

Waste Minimisation Guide for the Textile Industry

A Step Towards Cleaner Production

Volume I Appendices

Appendix 1: Waste Minimisation Options for the Textile Industry

Appendix 2: Case Studies

Appendix 3: Typical Pollution Loads from the Textile Industry

Appendix 4: End-of-pipe Treatment Methods

Appendix 5: References, Bibliography and Recommended Readings

Appendix 6: Supporting Data

Appendix 7: Useful Organisations

Appendix 8: Sample Presentation

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Appendix 1

Waste Minimisation Options for the Textile Industry

This Appendix contains detailed descriptions of the various waste minimisation options that are available for the textile industry. They are divided into 2 main sections:

- w General waste minimisation suggestions for reducing water, chemical and energy consumption; reducing solid waste; reducing air and noise pollution; and minimising the emission of toxic substances.
- w Specific waste minimisation suggestions for each textile process.

A more detailed description of these options can be found in the literature and it is suggested that you refer to the following books / reports :

- w **Best Management Practises for Pollution Prevention in the Textile Industry**, United States Environmental Protection Agency (1996);
- w **Water and Chemical Use in the Textile Dyeing and Finishing Industry**, Environmental Technology Best Practice Programme (1997);
- w **The Textile Industry and the Environment**, United Nations Environment Programme (UNEP) (1994);
- w **Cleaner Technology Transfer to the Polish Textile Industry - Idea Catalogue and Selected Options**, Danish Environmental Protection Agency (1997).

A1.1 Reducing Water Consumption

Water consumption in a textile factory can be reduced by implementing various changes ranging from simple procedures such as fixing leaks, to more complex options such as optimising water use and reducing the number of process steps. Some suggestions are outlined in this section.

A1.1.1 Repair Leaks, Faulty Valves, etc.

A simple method of determining if leaks exist is to take incoming water meter readings before and after a shut-down period when no water is being used. A difference in the readings could indicate a leak.

A1.1.2 Turn off Running Taps and Hoses

Encourage workers to turn off taps and hoses when water is not required. The fixing of hand triggers to hoses also reduces water consumption.

A1.1.3 Turn off Water when Machines are not Running.

Encourage workers to turn off machines and water during breaks and at the end of the day. Avoid circulating cooling water when machines are not in use.

A1.1.4 Reduce the Number of Process Steps.

This involves a study of all the processes and determining where changes can be made. For example, fewer rinsing steps may be required if a dye with high exhaustion is used.

A1.1.5 Optimise Process Water Use.

Examples include using batch or stepwise rinsing rather than overflow rinsing, introducing counter-current washing in continuous ranges, and installing automatic shut-off valves.

A1.1.6 Recycle Cooling Water

Cooling water is relatively uncontaminated and can be reused as make-up or rinse water. This will also save energy as this water will not require as much heating.

A1.1.7 Re-use Process Water

This requires a study of the various processes and determining where water of lower quality can be used. For example, final rinse water from one process can be used for the first rinse of another process.

A1.1.8 Using Water Efficient Processes and Equipment

Although replacing outdated equipment with modern machines which operate at lower liquor ratios and are more water efficient requires capital investment, the savings that can be made ensure a relatively short pay-back period.

A1.1.9 Sweeping Floors

Instead of washing the floors of the dyehouse and kitchens, rather sweep up any spillages and wash down only when essential. Not only will this reduce water use, but also the concentration of contaminants to drain as the waste is disposed of as solids.

A1.1.10 Reusing Water from Auxiliary Processes

The water used in the rinsing of ion-exchange columns and sand filters can be reused elsewhere in the factory.

A1.2 Reducing Chemical Consumption

The majority of chemicals applied to the fabric are washed off and sent to drain. Therefore, reducing chemical consumption can lead to a reduction in effluent strength and therefore lower treatment costs, as well as overall savings in chemical costs. Various options for reducing chemical use are listed below :

A1.2.1 Recipe Optimisation

Recipes are generally fail-safe designed which results in the over-use of chemicals. Optimising the quantity of chemicals required will lead to more efficient chemical use and lower costs. Continual updating of recipes should be carried out when new dyestuffs enter the market as, in general, less of these chemicals are required.

A1.2.2 Dosing Control

Overdosing and spillages can be reduced by mixing chemicals centrally and pumping them to the machines. Check that manual measuring and mixing is carried out efficiently and automatic dispensers are properly calibrated.

A1.2.3 Pre-screen Chemicals and Raw Materials

Avoid dyestuffs containing heavy metals, solvent-based products and carriers containing chlorinated aromatics. Safety data sheets should be obtained from the chemical manufactures to obtain information such as toxicity, BOD and COD. Check that raw materials do not contain toxic substances. Check that companies will accept expired raw materials for disposal.

A1.2.4 Chemical Substitution

Review chemicals used in the factory and replace those hazardous to the environment with those that have less of an impact. Use dyes that have high exhaustion rates and require less salt.

Specifically :

- w replace metal-containing dyes
- w use bi-reactive dyes in place of mono-reactive
- w avoid the use of APEO detergents and replace with more biodegradable alternatives
- w replace stilbene optical brighteners with alternatives, or eliminate altogether
- w dye wool with dyes that do not require after-chroming

A1.2.5 Correct Storage and Handling

More effective control of the storage and handling of chemicals will result in less spillages reaching the drains.

A1.2.6 Chemical Recovery and Reuse

Chemical use may be reduced through recovery and reuse. For example, sodium hydroxide from mercerising can be recovered through evaporation. Dye baths may be reused and size can be recovered for reuse.

A1.2.7 Process Changes

Investigate the feasibility of changing to cold-pad batch dyeing. This results in less chemicals being used (and in particular, salt) and reduces water consumption significantly.

A1.2.8 Improve Scheduling

Review the scheduling of continuous processes such as sizing, desizing, padding etc. to ensure that the same chemical bath is used as many times as possible, thus reducing the number of dumps to drain per day.

A1.3 Energy conservation

As with water conservation, reductions in energy use can result in substantial savings and lower emissions from boilers or generating plants. Some energy efficient options are listed below.

A1.3.1 Compressed Air

Optimise compressed air generation

To keep generation costs to a minimum:

- w pressure control should be based on the pressure at the most sensitive / critical pieces of machinery;
- w compressor sequencing should be based on a narrow pressure band in order to achieve the minimum generation pressure at all times. Care should be taken, however to avoid excessive cycling.

Reducing generation pressure by 10% will yield savings of 5% of annual compressor operating cost.

Fix compressed air leaks

No-load tests should be carried out regularly, approximately every 2 to 3 months. All air leaks should be tagged and repaired at the earliest opportunity. Ultrasonic detection devices are available to assist in leak detection.

Optimise compressor sizing

Compressors should be sized as closely as possible to the duty. It is not economical to run any machine for long periods at low loads; the off-load power consumption can be between 15% to 70% of on-load power once motor inefficiencies have been taken into account. In general, reciprocating compressors offer the highest part-load operating efficiency, if it is well maintained

Install compressor control systems

For multiple compressor installations, a modern compressor control system can save between 5% and 20% of total generation costs for a modest capital outlay. Many modern controllers comprise cascade control, run-on timers and pressure control. The latter is important in installations where the demand for air fluctuates significantly. It enables a lower generation pressure at times when air demand (and therefore system pressure drops) is reduced.

General housekeeping

The following general items should be considered when addressing compressed air efficiency:

- w Ensure that the air fed to compressors is as cool as practicable. A 4°C drop in inlet temperature will give savings of 1% of generation efficiency. Air-cooled

compressors should be fitted with ductwork to atmosphere, such that the exiting warm air does not overheat the plantroom.

- w Ensure that air dryers are installed downstream of the air receiver. The receiver acts as a pre-drier. Only dry (or treat) compressed air for processes that require it. If air lines are subject to condensate problems, fit appropriate drainage points.
- w For all end-users of compressed air, ask the following questions:
 - { Does it need to be operated by compressed air at all?
 - { Is the supply pressure greater than necessary?
 - { Is there an adequate facility to isolate the supply line when not in use?

A1.3.2 Refrigeration

Reduce Cooling Loads

The most common application of refrigeration in Southern African textiles industries is for the provision of air conditioning of production areas. There are two issues here.

- w Ensure that heat gains (from machinery, unnecessary air ingress, lighting, etc.) are kept to a minimum. Bear in mind that heat gains from electrical machinery operating when not needed is paid for twice: once to operate the machine and again to remove the heat gain.
- w Ensure that the control temperature is set to an acceptably high level. Do not over-cool.

Decrease Condensing Temperature

Causes of unnecessarily high condensing temperatures include:

- w Non-condensable gas build-up in the condenser
- w Liquid refrigerant backing-up into the condenser
- w Head pressure control set too high
- w Fouling of the condenser heat exchanger
- w Fan and pump malfunction

As a guideline, reducing condensing temperature by 1°C will yield savings of between 2% and 4% of annual refrigeration cost

Increase Evaporating Temperature

Causes of unnecessarily low evaporating temperatures include:

- w Low refrigerant charge. Excessively low refrigerant charge can lead to gas by-passing of the expansion valve, increasing costs by 30 % or more.
- w Fouling of the evaporator heat exchanger.
- w Control temperature set too low.
- w Poor expansion valve performance.

As a guideline, increasing evaporator temperature by 1°C will yield savings of between 2% and 4% of annual refrigeration cost

Compressor Control

The type of control strategy adopted can have a significant effect on operating costs. An effective control strategy could be adopted using the following guidelines:

- w Avoid excessive part-load operation.
- w Ensure that compressors are sequenced to avoid operating more than one compressor at part-load at any one time.
- w Use reciprocating compressors for part-load operation, in preference to screw or centrifugal types.
- w Avoid the use of compressor capacity control mechanisms that throttle the inlet gas flow, raise the discharge pressure or use gas by-pass.
- w Ensure that all auxiliaries are switched off when the compressor is off.

Incorrect control of compressors can increase costs by 20%, or more. Poor control of auxiliaries can increase costs by 20%, or more.

A1.3.3 Steam Generation

Boiler blowdown

It is necessary to control the build-up of total dissolved solids (TDS) within any steam-raising boiler, through periodic blowing-down. It is essential that boiler TDS is monitored regularly in order that excessive blowing down is avoided. Increasing blowdown by 5% will increase fuel consumption by between 1% and 1.5%.

Economisers

Boiler efficiency may be increased by preheating feedwater through the use of an economiser installed within the boiler flue. In general, **an increase in feedwater temperature will result in 1% less fuel being burned at the boiler.**

Combustion air temperature

Boiler efficiency can be increased by recovering waste heat from the flue gas and preheating combustion air. **An increase in combustion air temperature will result in about 2% efficiency increase.**

Firing rate and load variation

Highest boiler efficiencies generally occur over the range of firing rates from 70% to 90% of rated capacity. Boiler efficiency can be optimised, therefore, by ensuring, as far as possible, that equipment is used within this range.

Fluctuating loads have adverse effects on boiler efficiency, especially if frequent periods of low load are a characteristic. There are several ways to improve this situation:

- w rationalisation of the load demand, if possible. Steam accumulators enable a dampening effect of load variation.
- w rationalisation of boiler firing schedule.
- w improvements to the firing control system.
- w installation of a flue-gas shut-off damper to eliminate the circulation of cold air in the event of boiler shut-down.
- w installation of a number of smaller boilers as opposed to a single large one.

A1.3.4 Steam Distribution and Use

Insulation

All hot surfaces of a steam distribution system must be insulated. Justification can be made on the grounds of a reduction of heat loss, improvement in steam quality (through reduced condensate formation) and health and safety issues.

Heat loss charts are available for various combinations of pipework diameters and surface temperatures over a range of insulation thicknesses. As a rough guide, **insulation can be economically justified to reduce bare pipe losses by 90%.**

Flash steam recovery

Flash steam is generated when hot condensate is allowed to reduce in pressure, allowing a certain amount of condensate to evaporate (flash). The total heat content of the new system at equilibrium is the same as the total heat content of the original condensate. The quantity of flash steam generated may be calculated using a flash steam chart, or from steam tables. Wherever the generation of flash steam occurs, it is important to consider alternative possible uses for it (this includes the use of flash steam from boiler blowdown).

Good housekeeping

The following guidelines should be used to ensure good housekeeping of steam distribution systems:

- w All steam traps should be surveyed annually to ensure their correct operation.
- w Ensure that all steam leaks are attended to at the earliest opportunity.
- w Reduce temperature levels to the minimum required by the process.
- w Optimise end-user requirements by ensuring that the plant is fully loaded when possible and shut down (isolated) when not operational.
- w Ensure that end-user heat exchanger surfaces are maximised by provision of adequate air venting (during start-up only) and steam trapping.
- w Valve off steam supply lines that are out of use for considerable periods.
- w Consider heating small, distant or occasional users by other means.

A1.3.5 Install Heat Exchangers

The installation of heat exchangers on the high temperature effluent streams to recover energy and heat incoming water results in substantial savings.

A1.3.6 Optimise Plant Environmental Conditions

Optimise the temperature, humidity etc., of the factory so that only the required amount of energy is used.

A1.3.7 Shutting off of Lighting, Air-conditioning, etc.

Shutting off the lights in areas not in use and during shut down periods will reduce electricity costs, as will turning off the air-conditioning over weekends and shut-downs. Shutting off machines when not in use also results in savings.

A1.4 Reducing Air Pollution

Some steps to reduce the emissions to air include:

- w Decreasing emissions of organic solvents by changing to water-based products.
- w Using scrubbers to collect particulate matter.
- w Optimising boiler operations to reduce the emissions of nitrous and sulphur oxides.
- w Pre-screening chemicals using the Material Safety Data Sheets to ensure that chemicals are not toxic.
- w Identifying sources of air pollution and quantifying emissions.
- w Designing and manufacturing products that do not produce toxic or hazardous air pollutants.
- w Avoiding fugitive air emissions from chemical spills through improved work practices.

A1.5 Reducing Solid Waste

In terms of volume, solid waste is the second largest waste stream in the textile industry next to liquid effluent. There are a number of waste minimisation options available to reduce solid waste, and these include :

- w Reducing the amount of packaging material by improved purchasing practices such as ordering raw materials in bulk or returnable intermediate bulk containers (IBCs). This reduces spillages, handling costs, exposure of workers to chemicals and the amount of storage space required.
- w Purchasing chemicals in returnable drums. Enquire if vendors will accept unwashed drums as this will reduce the waste water generated in the factory.
- w If possible, ordering chemicals in IBCs rather than bags as these are easily broken, causing spillages.
- w Purchasing yarn on reusable plastic cones rather than cardboard cones.
- w Reducing seam waste through effective training programmes.
- w Selling waste fibres, sweeps, rags, yarn and cloth scraps.

- w Selling used pallets to a recycler.
- w Donating damaged pallets to institutions (e.g. schools) for the wood.

A1.6 Reducing Toxicity

Compounds that contribute to the aquatic toxicity of textile effluent include salt, metals, surfactants, toxic organic chemicals, biocides and toxic anions. Some methods of reducing the use of these compounds are to :

- w Reduce metal content through careful pre-screening of chemicals and dyes for metal content and using alternatives where possible.
- w Eliminate galvanised plumbing as reactions with brass fittings can take place in the presence of acids, alkalis or salt and lead to the release of zinc.
- w Reduce the amount of salt in the effluent by optimising recipes, using low-salt dyes, reusing dyebaths and optimising dyeing temperatures.
- w Use biodegradable surfactants such as linear alcohol ethoxylates.
- w Replace chlorinated solvents with unchlorinated alternatives.
- w Replace the use of biocides with ultraviolet light as a disinfectant for cooling towers.
- w Carefully pre-screen chemicals for their toxic nature using MSDS.

A1.7 Reducing Noise Pollution

The following steps can be implemented to reduce noise pollution :

- w install screens and sound baffles on fans,
- w regular maintenance of machinery,
- w fit anti-vibration mounts on machines, and
- w fit walls with sound-absorbing material.

A1.8 Waste Minimisation in Specific Textile Processes

The following sections will describe various waste minimisation techniques that can be implemented in specific textile processes.

A1.8.1 Sizing

Size selection

Replace starch-based sizes with synthetic sizes. The advantages of this is a reduced pollution load as synthetic sizes have lower BOD levels, and they can be recycled for reuse.

Raw materials

Test incoming raw materials for toxic compounds. Purchase size in bulk in drums rather than bags etc. as this produces less solid waste and reduces the chances of spills due to breakages.

Recipe optimisation

Ensure that only the minimum required size is added onto the yarn. This reduces chemical consumption as well as the pollution load to drain during desizing.

A1.8.2 Preparation Department

Preparation includes desizing, scouring, bleaching and mercerising. Desizing accounts for > 50% of the pollution load of preparation while scouring contributes between 10 and 25%. Good preparation is essential for subsequent processing as any impurities remaining on the fabric will interfere with the dyeing and finishing processes. Some waste minimisation options for the preparation department are listed below.

Desizing

The effluent from desizing will contain the sizes that were added onto the yarn before weaving/knitting. Using and recycling synthetic sizes in place of starch sizes will reduce the pollution load from desizing.

Scouring

- w Incoming raw material should be screened for toxic chemicals as these will be removed during the scouring process.
- w Detergents should be easily biodegradable. Avoid the following detergents: linear alkylbenzenesulphonate; nonylphenolethoxylate; dialkyldimethyl ammonium chloride; distearyl dimethyl ammonium chloride; di dimethyl ammonium chloride; sulphosuccinates; alkylphenolethoxylates; complexing agents with poor biodegradability (e.g. EDTA; phosphonic acid; NTA; phosphonates).
- w Reuse scour washwater for desizing. Recycle continuous scour washwater to batch scouring.

Bleaching

- w Replace the use of chlorites and hypochlorites with hydrogen peroxide.
- w Ensure that bleaching is carried out efficiently.
- w Recycle bleach washwater for scouring.
- w Use vacuum slots to remove excess solution which can then be reused

Singeing

Little or no pollution arises from singeing. Ensure that air scrubbers are installed to trap particles that are burnt off the fabric. Cooling water can be reused elsewhere in the factory. Remove lint from the pad solution to reduce the frequency of dumping.

Mercerising

Recycling of sodium hydroxide through evaporation for reuse in mercerising or scouring will decrease the pollution load and chemical consumption.

General

- w Use modern equipment.
- w Replace batch processes with continuous processes.
- w Install counter-current washing.
- w Combine processes such as desizing, bleaching and scouring.
- w Replace harmful chemicals with those of lower environmental impact.
- w Reuse washwater for cleaning equipment and screens.

A1.8.3 Batch Processing

There are a number of waste minimisation options for batch processing. These include :

- w Cascading multiple rinsing operations.
- w Reusing softening baths with reconstitution.
- w Reusing preparation baths (scouring and bleaching) with reconstitution after filtration to remove impurities.
- w Segregating coloured effluent streams from *clean* streams (preparation and rinsing) to ensure that only concentrated effluent is treated. This *clean* effluent may be used elsewhere in the factory.
- w Installing automatic shut-down of water in overflow cooling when the required temperature has been reached.
- w Replacing outdated machines with high liquor ratios with more modern equipment.
- w Carrying out softening on a pad mangle.
- w Replacing batch-wise rinsing with continuous rinsing with counter current flow.
- w General water, chemical and energy conservation measures as listed at the beginning of this Appendix (Sections A1.1 to A1.3).

A1.8.4 Dyeing

Batch dyeing

Careful selection of dyes is important. Dyes should have high fixation/exhaustion, low toxicity, absence of metals, and be appropriate for the end use. Correct and efficient application procedures must be used and right-first-time production should be achieved.

The main areas for waste minimisation include :

- w Using low liquor ratios.
- w Using automated dye and chemical dosing systems.
- w Reusing dyebaths, rinse water and softening baths.
- w Ensuring a good cloth preparation.
- w Optimising pH and salt for each recipe.
- w Avoiding the use of auxiliaries that reduce or retard exhaustion.
- w Using bireactive dyes.
- w Using the newer low-salt reactive dyes.
- w Optimising dyeing temperatures.
- w Avoiding the addition of more chemicals to offset the effects of other chemicals - use other non-chemical methods such as procedural or mechanical alterations or change the dye selection.
- w Replacing the use of acetic acid in neutralising after dyeing with formic acid or dilute hydrochloric acid (acetic acid adds to the COD of effluent).

Continuous dyeing

The main waste minimisation strategies in continuous dyeing are to :

- w Maximise dye fixation.
- w Minimise wash - off.
- w Avoid discards and machine cleaning wastes during start-up, shut-down and changes of colour and style.
- w Minimise the number of times a dyebath has to be dropped and cleaned due to a colour change by careful scheduling.
- w Use automated colour kitchens to minimise the working losses and discards.
- w Improve washing efficiency through the installation of flow restrictors to control water volumes. Use counter current washing procedures.
- w Optimise dosing of chemicals through monitoring of relevant parameters such as pH, absorbance, turbidity etc.

General waste minimisation options for dyeing

- w Operate at lowest possible bath ratio. This leads to a reduction in operating costs, water consumption, chemical use, energy use and less effluent discharge.
- w Minimise stripping and / or redyeing procedures.
- w Avoid shading additions.
- w Avoid the use of detergents to wash fabric after reactive dyeing; high temperatures are just as effective.
- w Minimise auxiliary use. Some auxiliaries interfere with dye fixation and should be replaced with alternatives or removed as this will reduce the colour load of the effluent. Some auxiliaries are added to compensate for inefficiencies in the process, equipment, or substrate design. Therefore, optimising these factors will reduce auxiliary use.
- w Right-first-time dyeings. Corrective measures are chemically intensive and have much less chance of achieving the required quality. The greatest costs in reprocessing are associated with the cost of dyes and chemicals - typically, the costs can increase by as much as 30%. Right-first-time dyeing leads to an

increase in productivity and more efficient use of resources (e.g. labour, capital).

- w In dyeing polyester, avoid the use of carriers by upgrading dye machinery or replace with less harmful alternatives.
- w Good fabric preparation. This increases the chance of right-first-time dyeing as fixation is improved.
- w Improved dye fixation. Dye fixation onto cotton can be improved by mercerising the yarn or fabric prior to dyeing.
- w Pad-batch dyeing. This is a cold dyeing method used mostly on cellulosics that results in a reduction in pollution, energy use, and costs. The advantages include :
 - { no salt or chemical specialities are required,
 - { more efficient use of dye,
 - { improved quality of dyeing,
 - { can be used on wovens or knits, and
 - { low capital investment results in savings in dyes, chemicals, labour and water.
- w Reuse dyebaths, especially those using dyes with high exhaustion such as acid or basic dyes. There are 4 main steps to follow :
 - { save the exhausted dyebath - this can be done by pumping it to a holding tank (or identical machine doing the same processes) and returning it to the machine for use in the next dyeing procedure.
 - { analyse the dyebath for residual chemicals - most auxiliaries do not exhaust in the dyeing process. There is approximately a 10% loss due to adsorption onto the fabric. Others however, are used or lost during the process and must be replaced. Unexhausted dyestuffs need to be analysed to determine the concentration remaining in the dyebath to ensure correct shading in further dyeings. Dyebath analysis can be performed using a spectrophotometer and specific guidelines for such a procedure.
 - { reconstitute the dyebath - water is added to replace that which is lost to evaporation or to the product. Auxiliaries are added in proportion to the water volume (these can be estimated) and finally the dyestuff is added for the required shade.
 - { reuse the dyebath - check the temperatures to ensure that the reused dyebath is the right temperature to minimise spotting and unlevel dyeings.

If properly controlled, dyebaths can be used for up to 15 or more cycles. Use dyes that undergo minimal changes during dyeing (acid, basic, direct and disperse) and reuse dyebaths to repeat the same shades.

Dyebath reuse is limited by impurity build-up from, for example, the fabric, salt build-up, steam contamination and surfactants. In addition, speciality chemicals may be lost during the dyeing process and these should be screened for their reuse potential. Close scheduling is also required which may limit the flexibility required for bath dyeing.

- w Water reuse. This can be achieved by dyeing multiple lots in the same dyebath. This is generally possible for those products where high quality dyeing is not essential (e.g. work gloves, hosiery).
- w Install improved machinery that have better controls.
- w Screen azo dyes to ensure that they do not degrade to produce amines that are listed as being toxic (**Appendix 3, Table A3.14**).
- w Metal containing dyes should be replaced where possible.

A1.8.5 Printing

Pollutants associated with printing include suspended solids, solvents, foam, colour and metals, and in general, large volumes of water are consumed during the washing-off stages. The main areas of waste minimisation in printing include raw material conservation, product substitution, process and equipment modifications, material handling, scheduling and waste recovery. Other options include :

- w Waste minimisation in the design stages can eliminate the need for dyes containing metals.
- w Careful selection of surfactants.
- w Reducing air emissions by replacing solvents with water-based alternatives.
- w Routine and careful maintenance of printing equipment.
- w Training employees in the practices of good housekeeping.
- w Reusing water from washing the print blanket.
- w Turning off wash water when machine is not running.
- w Installing automated colour kitchens.
- w Reusing left over print paste.
- w Removing excess paste from drums, screens and pipes by *dry* techniques (wiping with a squeegee etc.) before washing with water. This reduces the colour load discharged to drain.
- w Careful scheduling to prevent expiration of print pastes before use.
- w Investigating alternatives to urea as this increases the nitrogen in the effluent.

A1.8.6 Finishing

There are a number of finishing processes that are carried out on the fabric after dyeing and/or printing. These can be achieved by chemical or mechanical methods. Some waste minimisation options are listed below :

- w Design fabrics such that the need for chemical finishes are minimised.
- w Use mechanical alternatives to chemical finishes.
- w Use low add-on methods.
- w Minimise volatile chemical use.
- w Avoid mix discards through careful preparation.
- w Install automated chemical dispensing systems.
- w Train employees in good housekeeping practises.
- w Use formaldehyde-free cross-linking agents.
- w Reduce solid waste by reducing the need for selvedge trimming through better width control, training workers and collecting selvedge trim for resale.
- w Investigate the use of spray application of finishes as these have a low add-on and require no residual dumping at the end of a run.

Appendix 2

Case Studies

This chapter will discuss various case studies where textile companies have implemented successful waste minimisation programmes. The techniques used and the savings obtained will be highlighted. These case studies are taken from three main references : The **United Nations Environment Programme (1995)**, the **Environmental Technology Best Practice Programme (1997)**, and the **Environmental Protection Agency (1996)**.

CASE STUDY 1 : CONSERVING WATER, ENERGY AND CHEMICALS

Background

The Hitega textile mill in Chile is an integrated mill producing dyed yarn and fabric with an average ratio of 65 : 35 % polyester to rayon. Large volumes of water are used and various dyes, bleaches and chemicals are added.

Waste minimisation principle

Internal recycling; Process modification.

Description of implementation

- w Recycling of cone-dye cooling water for reuse.
- w Recycling water from the air-conditioning system.
- w Improving softener regeneration and service.
- w Improving maintenance of steam traps to prevent leaks.
- w Reducing suspended solids in effluent by installing screens in the dyehouse drains.

Three of these options were analysed in detail.

Economics

Option	Payback period
Recycling cooling water	20 months
Recycling aircon. system water	14 months
Softener system	24 months

Remarks

The implementation of these options results in savings in water, energy and chemicals.

Source

United Nations Environment Programme (1995) *UNEP / IEO ICPIIC International Cleaner Production Information Clearing House.*

CASE STUDY 2

SAVINGS THROUGH NEW TECHNOLOGY

Background

The Skjern Tricotage-Farveri textile mill in Denmark produces approximately 5 000 tons of fabric/annum. They are a major supplier to Novotex, a Danish company that sells ecologically sound cotton.

Waste minimisation principle

Material substitution.

Description of implementation

Raw cotton fabric requires bleaching, usually with hydrogen peroxide. The bleaching chemical has to be removed, generally through a number of rinsing stages or by the addition of a reducing agent to neutralise the bleach. In both cases, large volumes of water are used for rinsing.

Replacing the traditional reducing agent with an enzyme formulation considerably decreased water and energy use. The by-products of the reaction with hydrogen peroxide are oxygen and water. The enzyme is also biodegradable.

Economics

Approximately 15 to 30 US \$/ton fabric can be saved, depending on the local cost of water and energy.

	Savings / annum
Energy	2 780 GJ
CO ₂ emissions	160 t
Water	13 500 kl
Natural gas	70 800 kl

Remarks

The substitution of the enzyme formulation for traditional bleach clean-up methods results in savings in water, energy and process time.

Source

United Nations Environment Programme (1995) *UNEP / IEO ICPIIC International Cleaner Production Information Clearing House.*

CASE STUDY 3

SAVINGS THROUGH PROCESS CHANGE

Background

The Australian Dyeing Company is a commission dyehouse, processing knitted and woven fabrics. Dyeing of 100% cotton and cotton blends takes place on a large scale.

Waste minimisation principle

Application of new technology.

Description of implementation

- w Changing from the traditional exhaust dyeing methods to cold pad-batch processing. This removes salt from the effluent, reduces water consumption by 88% and decreases energy use.
- w The introduction of Cibracon C dyes which have greater levels of fixation, thereby reducing the colour entering the effluent stream.

Economics

A payback period of 8 months was achieved on the capital outlay.

Remarks

Cold pad-batch processing has a number of advantages such as improved product quality, larger runs of fabric of the same colour can be made, and it takes up less space on the production floor.

Source

United Nations Environment Programme (1995) *UNEP / IEO ICPIIC International Cleaner Production Information Clearing House.*

CASE STUDY 4

REDUCING WASTE AND ENERGY USE

Background

Quimica y textiles Proquindus SACI in Chile dyes a variety of materials for fabric manufacturers. It processes both wool and cotton fabrics.

Waste minimisation principles

Process modification; Material substitution; Improved house-keeping.

Description of implementation

37 waste minimisation options were identified which were divided onto groups according to the priority. Six of the 19 high priority options were costed in detail. These included :

- w repairing steam traps to reduce fuel consumption by 36%.
- w modifying rinsing techniques to reduce water consumption by 50%.
- w reducing sulphate in the effluent through chemical substitution.
- w improving process controls, screening drains, regular cleaning of sumps, repairing steam leaks, improving dyeing equipment etc.
- w recycling of solid waste before disposal.

Economics

Action	Payback period
replacing leaking steam taps	1 week
modifying rinsing process	< 1 week
replacing sulphate with sodium chloride	immediate
repairing leaks in laundry	< 1 week
repairing leaks on washer	immediate
filtering sulphuric acid	2.5 years

Remarks

The implementation of these waste minimisation procedures saved on raw materials, water and energy, reduced toxic waste and improved product quality and operating efficiency.

Source

United Nations Environment Programme (1995) *UNEP / IEO ICPIIC International Cleaner Production Information Clearing House.*

CASE STUDY 5

SAVINGS THROUGH REDUCING ENERGY USE

Background

Dyeing of fabric requires large volumes of hot water. The recovery of heat from this used water using conventional heat exchangers is difficult due to clogging by fabric particles. An Irish wool and fabric dyeing textile mill investigated the use of a new design of heat exchanger.

Waste minimisation principle

New technology.

Description of implementation

A heat exchanger was designed in which there was turbulent flow through the machine to prevent fibres settling on the surface of the heat exchanger. This also improved heat transfer.

The temperature of the hot water was reduced from 95 to 38°C and cold water is heated from 10 to 67°C.

Economics

13.2 MJ of heat was saved annually. The payback period was less than 2 years

Source

United Nations Environment Programme (1995) *UNEP / IEO ICPIIC International Cleaner Production Information Clearing House.*

CASE STUDY 6

SAVINGS THROUGH DYEBATH REUSE

Waste minimisation principle

good housekeeping, improved operating practices, reuse of raw material.

Description of implementation

- w Replenishing dyes were added to used dye liquor at the end of a cycle.
- w Depletion of the dye carrier was higher than that of the dye, requiring higher recharge of dye carrier.

Economics

A payback period of months was achieved.

Remarks

Water use was more than halved and energy consumption also decreased.

Source

United Nations Environment Programme (1995) *UNEP / IEO ICPIIC International Cleaner Production Information Clearing House.*

CASE STUDY 7

REUSE OF WATER AND CHEMICALS USING NEW TECHNOLOGY

Background

Water and chemicals in the effluent from Italian textile dyeing mills was treated and recovered for reuse by reverse osmosis.

Waste minimisation principle

New technology.

Description of implementation

- w Three main steps are involved :
 - { biological treatment,
 - { physico-chemical treatment, and
 - { reverse osmosis.
- w These are followed by conventional decolourising, concentration and make-up before being reused as process water.
- w The pollutants are virtually eliminated and the recovered water improves textile quality when recycled.
- w 95 % of the water is recovered, energy is saved and chemicals are reused.

Economics

Capital and operating costs are quite high, but the payback period is 1 to 2 years of the plant operation.

Remarks

The plant paid for itself in a short period. This process reduced pollution and makes wiser use of raw materials, thereby saving water, chemicals and energy.

Source

United Nations Environment Programme (1995) *UNEP / IEO ICPIIC International Cleaner Production Information Clearing House.*

CASE STUDY 8

REDUCING COD IN THE TEXTILE INDUSTRY

Background

The Misr Spinning and Weaving Company is situated in Egypt.

Size agents are essential during the weaving process, but can interfere with dyeing and, therefore, need to be completely removed after weaving. Commonly used sizes are those based on starch. The wash water for this process contains these size chemicals which contribute significantly to the COD of the effluent.

Waste minimisation principle

Material substitution.

Description of implementation

- w Reducing the COD occurs through substitution of the starch size with one that can be reclaimed by ultrafiltration.
- w Starch was replaced by water-soluble starches, mixtures of water-soluble starches and PVA, PVA and CMC.
- w A UF plant was installed.

Economics

- w 80% of size was reclaimed.
- w 90% of hot water used in rinsing could be reused.
- w There were decreased costs in weaving due to improved sizes.
- w It eliminates the need for processes to solubilise the original starch sizes (oxidative, enzymatic etc.).
- w Less energy is required.
- w Payback period is estimated to be 8 to 18 months for a medium-sized European textile mill.

Remarks

This process allowed recovery of the most significant pollutant, reduced water, chemical and energy consumptions, reduced production costs and improved the quality of the fabric.

Source

United Nations Environment Programme (1995) *UNEP / IEO ICPIIC International Cleaner Production Information Clearing House.*

CASE STUDY 9

RECOVERING WATER AND CHEMICALS

Background

The Chieng Sang Industry Co. Ltd is a medium scale dyeing plant in Thailand. It produces mainly a cotton-polyester blend.

Waste minimisation principle

New technology.

Description of implementation

- w Installation of a EVAC vacuum suction system to recover and reuse finishing chemicals. This also resulted in a more even distribution of chemicals. A 25% savings in chemicals was achieved.
- w Installation of a computerised spectrophotometer to match colours more accurately. Process efficiency was improved and re-dyeing has been cut by 70% resulting in a reduction in chemical consumption by 20%.
- w Condensate is recovered and reused in the boiler after make-up.
- w Cooling water is reused for rinsing fabric after dyeing.

Economics

- w Savings from condensate and cooling water :
 - { 140 kl steam/d
 - { 30 kl cooling water/d
 - { 3% of fuel
- w Significant savings are also made owing to a reduction in waste water volumes and therefore effluent treatment.
- w The payback period is estimated to be 3.5 years.

Remarks

The implementation of these waste minimisation option resulted in an increase in productivity, savings in water, chemicals and fuel and a reduction in the pollution load of the effluent.

Source

United Nations Environment Programme (1995) *UNEP / IEO ICPIIC International Cleaner Production Information Clearing House.*

CASE STUDY 10

SAVING WATER BY IMPROVED HOUSEKEEPING

Employees at a small hat dyeing company left hoses running after cooling the hats as part of the manufacturing process. By simply fixing hand triggers to the hoses, effluent costs were reduced by approximately GBP 2 000 / year.

Source

Environmental Technology Best Practice Programme (1997) *Water and Chemical Use in the Textile Dyeing and Finishing Industry*, United Kingdom.

CASE STUDY 11

SAVING WATER THROUGH PROCESS MODIFICATION

Instead of softening in a final rinse, a Leicester-based textile mill softens fabric in a pad-batch process. This reduces the number of process steps and the process time, resulting in savings in water, chemicals and energy and an increase in production.

Source

Environmental Technology Best Practice Programme (1997) *Water and Chemical Use in the Textile Dyeing and Finishing Industry*, United Kingdom.

CASE STUDY 12

SAVING WATER THROUGH RECYCLING AND REUSE

Recycling of their cooling and condensate water saves a medical textile company in Lancashire 11 000 kl of borehole water. Estimated savings in effluent disposal are about GBP 3 000/year. In addition, recycling of the last rinse water from beam and winch dyeing saves a further 7 000 kl of water and about GBP 2 700 in effluent disposal costs.

A Wigan-based dyer and finisher halved its water consumption by recycling the bleach effluent for the scouring process. Approximately GBP 10 300/year are saved in effluent disposal costs.

Source

Environmental Technology Best Practice Programme (1997) *Water and Chemical Use in the Textile Dyeing and Finishing Industry*, United Kingdom.

CASE STUDY 13

SAVINGS THROUGH CHEMICAL SUBSTITUTION

A Scottish finishing company saves GBP 20 000/year in effluent disposal costs by reducing the COD of their effluent from 2 460 mg/l to 700 mg/l. This was achieved through replacing the use of soap in scouring with anionic/non-ionic detergents and conducting trials to ensure that minimum detergent was used.

Source

Environmental Technology Best Practice Programme (1997) *Water and Chemical Use in the Textile Dyeing and Finishing Industry*, United Kingdom.

CASE STUDY 14

WATER SAVINGS THROUGH DYEBATH REUSE

Background

The Adams-Millis textile company has two mills located in North Carolina and conducts batch dyeing of nylon pantyhose.

Waste minimisation principle

Segregation, direct reuse, scheduling, audit and analysis.

Description of implementation

Direct dyebath reuse for the dyeing of nylon pantyhose was implemented in rotary drum dyeing machines.

Economics

Water use was decreased by 35% and energy use reduced by 57%.

Source

Environmental Protection Agency (1996) *Best Management Practices for Pollution Prevention in the Textile Industry*, U.S. Environmental Protection Agency, Document No. EPA/625/R-96/004, Ohio, USA.

Appendix 3

Typical Pollution Loads from the Textile Industry

This appendix summarises the typical water consumption and pollution loads from the various processes in the textile industry. This includes liquid effluent, solid waste and energy use.

A3.1 Liquid Effluent

The specific water intake for the textile industry varies from 95 to 400 l/kg fabric depending on the type of processes used and water efficiency (Steffen Robertson and Kirsten, 1993). Dyehouse effluents are complex, containing a wide and varied range of dyes and other products such as dispersants, levelling agents, acids, alkalis, salts and sometimes heavy metals (Laing, 1991). Emissions to water consist of concentrated waste process water, rinsing and cooling water. Rinsing water may represent 60% to 70% of the total water consumption (Swedish Environmental Protection Agency, 1989). The waste water contains natural impurities extracted from the fibres and a mixture of the process chemicals such as organic compounds, dissolved inorganic salts, dyes and heavy metals. In general, the effluent is highly-coloured, high in biological oxygen demand (BOD) and chemical oxygen demand (COD), has a high conductivity and is alkaline in nature. **Table A3-1** lists the typical pollution characteristics of the effluent from the textile industry (Environmental Monitoring Group, 1993, Kothuis and Schelleman, 1995, Cooper, 1978).

Table A3-1 : Effluent characteristics from the textile industry		
Process	Composition	Nature
sizing	starch, waxes, carboxymethyl cellulose, polyvinyl alcohol	High in BOD and COD
desizing	starch, glucose, carboxymethyl cellulose, polyvinyl alcohol, fats and waxes	high BOD, COD, suspended solids, dissolved solids
scouring	caustic soda, waxes, grease, soda ash, sodium silicate, fibres, surfactants, sodium phosphate	dark coloured, high pH, high COD, dissolved solids
bleaching	hypochlorite, chlorine, caustic soda, hydrogen peroxide, acids, surfactants, sodium silicate, sodium phosphate	alkaline, suspended solids
mercerising	caustic soda	high pH, low COD, high dissolved solids
dyeing	various dyes, mordants, reducing agents, acetic acid, soap	strongly coloured, high COD, dissolved solids, low suspended solids, heavy metals
printing	pastes, starch, gums, oil, mordants, acids, soaps	highly-coloured, high COD, oily appearance, suspended solids
finishing	inorganic salts, toxic compounds	slightly alkaline, low BOD

Table A3-2 : Specific pollution loads for various textile mills							
Fibre processed and factory operation	pH	SWU (l/kg)	SEV (l/kg)	SPL (g/kg)			
				COD	TDS	TSS	SO ₄
Polycotton/cotton woven fabric finishing	9.3	284	227	345		317	225
Cotton woven fabric finishing	9.9	140	115	64	409		
cotton/synthetics woven fabric finishing	6.9	277	222	352	495	365	170
cotton knit fabric finishing	9.7	256	309	159	762	660	
cotton/synthetics woven fabric finishing	11	<151	113	304	548	277	40
synthetics/cotton woven fabric finishing	6.5		226	43	349	216	67
All fibres knit fabric finishing; commission dyeing	8.5	364	106	9	101	62	19
All fibres commission dyeing		120	138				
synthetics/cotton knit fabric finishing			113				
cotton accessory/haberdashery		173	413				

Table A3-2 gives the specific water use (SWU), specific effluent volume (SEV) and specific pollution loads (SPL) for various textile mills in South Africa (Steffen Robertson and Kirsten, 1993). As can be seen, the pollution load differs depending on the type of fabric processed. The effluent characteristics for the various stages in the processing of 100% cotton, 50/50 cotton-polyester blend, wool and synthetic fibres are given in the following sections.

A3.2 Pollution Load from the Processing of 100% Cotton

The two main processes carried out at a mill processing cotton are weaving, preparation and finishing. Sizing takes place with starches, modified cellulose and synthetics. The woven cloth can contain 8% to 15% size. In general, the effluent has a high pH, is coloured, has a BOD of approximately 300 mg/l and uses approximately 350 l/kg fabric. **Table A3-3** lists typical pollution loads and effluent volumes produced from a cotton mill (UNEP, 1996, Pollution Research Group, 1983, Kothuis and Schelleman, 1995, Cooper, 1978).

Table A3-3 : Typical pollution loads for the processing of 100% cotton							
Process	pH	SEV (l/kg)	BOD	COD	TSS	TDS	O & G
			kg per 1000 kg of product				
Desizing							
enzyme starch	6 - 8	2.5 - 9	45.5	91	89	5	5
acid starch	6 - 8		45.5	91	89.5	7.5	5
polyvinyl alcohol (PVA)	6 - 8		2.5	5	5	48	2.5
carboxymethyl cellulose (CMC)	6 - 8		4	8	5	45	9.5
Scouring							
unmercerised greige fabric	12.5	2.5 - 43	21.5	64.5	5	50	40
mercerised greige fabric	12.5		16.5	49.5	5	50	30
Mercerising							
greige fabric	12	231 - 306	13	39	5	148	10
scoured fabric	12		4	12	5	148	nil
bleached fabric	12		2	6	5	148	nil
Bleaching							
hydrogen peroxide	9 - 12	2.5 - 124	0.5	2	4	22	nil
sodium hypochlorite	9 - 12		1	4	4	5	nil
Dyeing							
fibre reactive HE dyes (woven)	12		6	24	-	180	
basic	6 - 7.5	149 - 300					
direct	6.5 - 7.6	14 - 53					
vats	5 - 10	8.3 - 166					
sulphur	8 - 10	24 - 212					

A3.3 Pollution Load from the Processing of 50/50 Cotton-polyester blend

Table A3-4 lists typical pollution loads from a South African textile factory processing a 50/50 blend of cotton-polyester (UNEP, 1996, Pollution Research Group, 1983).

Table A3-4: Effluent characteristics for a mill processing 50/50 cotton-polyester blend								
Source	Effluent (l/kg)	pH	OA	COD	BOD	TS	SS	TDS
			kg per 1000 kg product					
Desizing								
starch	12.5	6 - 8			38.5	97	77	20
PVA	12.5	6 - 8			2.5	55.4	5	50.4
CMC	12.5	6 - 8			3.93	59.5	5	54.5
mixture	4.2		9.7	74		78		
Scouring								
unmercerised	25	12			10.8	14.8	5	9.8
mercerised	25	12			8.34	14.7	5	9.7
Bleaching								
peroxide	16.7				1.3	24	4	20
oxidative-desize-bleach	5.1		23	23		184		
Mercerising								
poly/cotton	16.7				3.2	82	5	77
Dyeing								
disperse - vat	42	12		68	22.8	122		122
vat	100					150		
disperse	80					20		
direct - disperse		6 - 8		32	10.7			114
sulphur - disperse		11		68	22.8			69.7
reactive - disperse		12		41	13.8			192
Printing								
pigment (woven)		6 - 8		5	1.26		0.13	2.5
pigment (knit)		6 - 8		5	1.26		0.13	2.5
vat (woven)		10		86	21.5		25	34
vat (knit)		10		86	21.5		25	35
machine wash	100							
screen wash	7							
hose vessels	30							
pig. wash	12.5				1	3	0	3
Finishing								
resin finishing		6 - 8						22
resin finishing flat curing		6 - 8		25	6.32			17.3

A3.4 Pollution Load from Wool Processing

Effluent is produced in the scouring, dyeing, rinsing, fulling, carbonising and washing processes. Scouring removes natural impurities and the effluent is therefore oily, alkaline, high in solids and high in BOD. Wool fibre accounts for only 40% of mass, the remainder is impurities. Typical wastes for a mill that scours and finishes wool are given in **Table A3-5** (Cooper, 1978) and **Table A3-6** lists the pollution loads from the various processing steps (Kothuis and Schelleman, 1995, Cooper, 1978).

Table A3-5 : Typical wastes from wool processing	
Parameter	Value
BOD	900 to 3 000 mg/l
TS	3 000 mg/l
pH	9 to 10.5
SS	100 mg/l
alkalinity	600 mg/l
grease	100 mg/l
Cr	4 mg/l

Table A3-6 : Pollution loads from wool wet processing				
Process	pH	BOD (ppm)	TS (ppm)	Volume (l / kg)
Scouring	9 to 10.4	30 000 to 40 000	1 129 to 64 448	45.6 to 99.6
Dyeing	4.8 to 8.0	380 to 3 000	2 000 to 10 000	15.8 to 22.2
Washing	7.3 to 10.3	4 000 to 11 455	4 830 to 19 267	332 to 830
Neutralising	1.9 to 9.0	28	1 241 to 4 830	104 to 130
Bleaching	6.0	390	908	2.5 to 22.2

A3.5 Pollution Load from the Processing of Synthetic Fabrics

There are no natural impurities in synthetic fibres. Desizing is not required and very little scouring and bleaching takes place. The major fibres and liquid wastes produced from each process are given in **Table A3-7** (Cooper, 1978).

Table A3-8 (Steffen Robertson and Kirsten, 1993) lists the pollution loads from various synthetic textiles, while **Table A3-9** lists the pollution load per process (Kothuis and Schelleman, 1995, Cooper, 1978).

Table A3-7 : Effluent characteristics from processing of synthetic fibres		
Fibre	Process	Liquid waste
Rayon	scour and dye	oil, dye, synthetic detergent, antistatic lubricants
	scour and bleach	synthetic detergents, hydrogen peroxide
	salt bath	synthetic detergent, chloride or sulphate
Acetate	scour and dye	antistatic lubricant, dye, sulphonated oils, synthetic detergent, esters, softeners
	scour and bleach	synthetic detergents, hydrogen peroxide or chlorine
Nylon	scour	antistatic lubricants, soap, soda, fatty esters
	developed disperse dye	dye, sodium nitrate, hydrochloric acid, developer, sulphonated oils
	bleach	peracetic acid
Acrylic	dye	dye, formic acid, wetting agents, aromatic amines, retarding agent, sulphates
	thermosol dyeing	acid
	bleach	chlorite
	scour	synthetic detergent, pine oil

Table A3-8 : Typical pollution loads for synthetic textiles					
Fabric	Vol. (l/ kg)	BOD	COD	SS	TDS
		kg per 1000 kg product			
Rayon	42	30	52	55	100
Acetate	75	45	78	40	100
Nylon	125	45	78	30	100
Acrylic	210	125	216	87	100
Polyester	100	185	320	95	150

Table A3-9 : Pollution loads from each process step for various synthetic textiles					
Process	Fibre	pH	BOD (ppm)	TS (ppm)	Volume (kl / 1 000 kg)
Scour	nylon	10.4	1 360	1 882	50 to 66
	rayon	8 to 9	2 800	3 300	17 to 34
	acetate	9 to 10	2 000	2 000	25 to 84
	acrylic	9.7	2 190	1 874	50 to 66
	polyester	8 to 10	500 to 800	600 to 1 400	25 to 42
Scour and dye	rayon	8.5	2 832	3 334	17 to 33
	acetate	9.3	2 000	1 778	33 to 50
Dye	nylon	8.4	368	641	17 to 33
	rayon	8 to 9	2 800	3 500	16.7 to 34
	acetate	9 to 10	2 000	2 000	34 to 50
	acrylic	1.5 to 3.7	175 to 2 000	833 to 1 968	17 to 33
	polyester	6 to 9	480 to 27 000	300 to 3 000	17 to 33
Salt bath	rayon	6.8	58	4 890	4 to 12
Final scour	acrylic	7.1	668	1 191	66 to 83
	polyester		650		17 to 33
Finishing	rayon				4 to 12
	acetate				25 to 42
	nylon				33 to 50
	acrylic				42 to 58
	polyester				8.3 to 25

A3.6 Solid Waste

The textile industry produces a variety of solid waste and, by volume, it is the second largest waste stream after liquid effluent. The source of solids waste includes waste fibre; tarry residues on stenters from finishing chemicals; hydrocarbons, dyes and chemicals from solvent recovery systems; sludge from effluent treatment plants; dye containers, which contain approximately 28g to 56g excess dyestuffs; chemical containers (potentially hazardous); pallets; fly ash and general paper trash.

The quantity and type of solid waste produced depends on the nature of the operation, the efficiency of the processes and the level of awareness about solid waste management. A survey in 1994 found that, by tonnage, the largest waste was due to paper followed by wastewater sludge, cardboard and fly/bottom ash (EPA, 1996). Optimising the operation of the wastewater works can lead to a reduction in sludge and introducing energy conservation measures will decrease the amount of fly ash produced as less incineration is needed. Solid waste from packaging materials can be reduced through more efficient stock control (buying in bulk) and purchasing chemicals in returnable containers.

Table A3-10 lists the various sources of solid wastes in the different manufacturing processes and the quantity produced (Kothuis and Schelleman, 1995, Cooper, 1978).

Table A3-10 : Source and type of solid waste produced in the textile industry		
Waste	Source	kg / ton fabric
Wool scouring		
dirt and wool	sorting and blending	12
dirt and vegetable matter	scouring	26
fly and sweeps	drying	2
wool waste	top preparation	55
wasted sludge	effluent treatment	570 (dry)
retained sludge	effluent treatment	780 (dry)
Wool fabric dyeing and finishing		
flock	carbonising and drying	16
seams	scouring	0.7
dye containers	dyeing	1.3
chemical containers	dyeing, finishing	1.6
fabric	finishing	1.3
flock	mechanical finishing	17
fibre	pre-treatment screening	25 (dry)
wasted sludge	effluent treatment	none
retained sludge	effluent treatment	1.6 (dry)
Woven fabric dyeing and finishing		
cloth	singe and desize	0.2
cloth	mercerise	0.1
cloth	bleach and wash	0.2
cloth	mechanical finish	6
flock	mechanical finish	4
dye containers	dye / print	0.5
chemical containers	dye, printing, finishing	0.8
fibre	pre-treatment screening	0.8 (dry)
wasted sludge	effluent treatment	20 (dry)
retained sludge	effluent treatment	67 (dry)
Knit fabric dyeing and finishing		
cloth	dyeing, printing	2
cloth	chemical finish	4
cloth	mechanical finish	3
dye containers	dye, printing	0.9
chemical containers	dye, printing, finishing	0.9
cloth	wash	2 (dry)
fibre	pre-treatment screening	0.8 (dry)
wasted sludge	effluent treatment	none
retained sludge	effluent treatment	64 (dry)
Greige goods		
fibre and yarn	yarn preparation	32
fibre, yarn, cloth	knitting	10
fibre, yarn, cloth	weaving	11
Carpet dyeing and finishing		
yarn and sweeps	tufting	1
selvage	selvage trim	26
flock	fluff and shear	4
dye containers	dyeing, printing	0.13
chemical containers	dyeing, printing	0.18
fibre	pre-treatment screening	1.2 (dry)
latex sludge	effluent treatment	2.3 (dry)
wasted sludge	effluent treatment	none
retained sludge	effluent treatment	5.2 (dry)
Yarn and stock dyeing		
yarn	bleaching, dyeing	0.7
yarn	beaming, winding etc.	5.4
dye containers	dyeing	0.87
chemical containers	dyeing, finishing	2.2
fibre	pre-treatment screening	9.0 (dry)
wasted sludge	effluent treatment	none
retained sludge	effluent treatment	2.9 (dry)

A3.7 Emissions to Air

Air pollution results from various textile processes and from energy production and has been identified as the second greatest pollution problem for the textile industry. Those from process emissions include volatile organic substances and particulate matter from the printing, dyeing, and curing of fabric, and the handling of chemicals. The emission of volatile organic substances may lead to the production of photochemical oxidants and cause unpleasant odours. The textile industry requires a great deal of heating and the type of fuel determines the nature of the pollutants. Boilers are one of the major point sources for air emissions, producing nitrogen and sulphur oxides. Fugitive sources of air pollution include volatile emissions from processed fabric stored in warehouses and chemical spills. Emissions to air can be minimised by designing products that do not require the use of volatile chemicals, optimising boiler operations and reducing the use of solvents.

A3.8 Noise Pollution

Noise in the textile industry arises from fan systems, transport to and from the industry and mechanical equipment.

A3.9 Hazardous Waste

Hazardous wastes are defined as wastes, or combination of wastes, that pose a threat to human health or living organisms because they are lethal, non-degradable, persistent in nature and can cause detrimental cumulative effects. These wastes can be solids, liquids, gas or sludges.

Most textile operations produce little or no hazardous waste, but some (10 to 20%) may be generators of hazardous waste. The main sources from the textile industry are heavy metals and solvents. Other components include acids, alkalis, bleaches, adhesives, polymers, cross-linking agents, detergents, dye carriers, chemical finishes, biocides, weed killers, paint strippers and solvents. The remainder (75% (m/m)) are considered to be non-hazardous. Carriers containing chlorinated aromatics are considered to be extremely hazardous and their use today is limited (Swedish Environmental Protection Agency, 1989). Organic phosphorous compounds (e.g. flame-proofing and complexing agents) may contain organic bromine compounds, such as decabromine diphenyl oxide and antimony trioxide, which are bioavailable and bioaccumulative.

The most effective means of reducing hazardous waste from the textile industry is one of avoidance by pre-screening all chemicals. This is most easily achieved by studying the material safety data sheet (MSDS). If Hazardous chemicals are required, proper handling and storage is important and workers should be trained in these areas.

A3.10 Dyes and the Environment

The loss of dyes to effluent can be estimated to be 10% for deep shades, 2% for medium shades and minimal for light shades (Laing, 1991). Dyes are present in the effluent at concentrations of 10 mg/l to 50 mg/l with 1 mg/l being visible to the naked eye. They are complex organic compounds which are refractory in aerobic treatment systems. Some contain metals such as Cr, Cu and Zn. Only 50% (m/m) is dye, the remainder is non-hazardous filler and surfactant.

There are 2 main factors involved in determining the risk assessment of chemicals, namely, hazard and exposure (Baughman, 1988). Hazard describes the potential biological effects (e.g. toxicity and carcinogenicity) that have a dose-response curve. Exposure is a measure of the expected environmental concentration of a chemical over time and distance. The data obtained from hazard and exposure studies will indicate what effects are possible, whereas risk assessment involves determining what is probable.

In the aquatic environment, dyes can undergo bioconcentration, ionisation, abiotic oxidation, abiotic and microbial reduction, precipitation and ligand exchange. The ionic dyes such as acid, direct, basic and metal complex dyes will not volatilise whereas, in principle, solvent, disperse, vat and sulphur dyes have the potential to be volatile. Sorption should also play a major role as dyeing is a sorption process. Hydrolytic reactions are not important because if the dyes survive the rigours of biological treatment processes, it is unlikely to degrade rapidly in the environment. Photochemical reactions may be important as dyes are good adsorbers of solar energy. However, little information is available on this. It is expected that anionic dyes would react with ions such as calcium and magnesium to form insoluble salts and thereby reduce the concentration available for other biological reactions. Similarly for basic dyes, due to their interaction with humic material and hydrous oxides. Redox reactions should also be considered, as in early vat dyeing processes, the dyes were reduced microbially before chemical replacements were introduced. Reduction in the environment would most likely occur under anaerobic conditions, however, the difficulties of working with anaerobic systems has limited research in this area. In general, there is very little literature available on the environmental behaviour of dyes. This is probably due to the lack of suitable analytical techniques.

A3.11 Toxicity

Dyes, especially, cause public concern as even small concentrations (1 mg/l) are visible in the environment. Safety data sheets should be available for each dyestuff where information regarding the toxicity, biodegradability, aquatic toxicity and the effect of exposure can be found. Toxicity is determined by carrying out tests on animals (usually rats) to ascertain the single oral dose of dye that will kill 50% of the population in 14 days. The results are

expresses in mg/kg of body weight and is known as lethal dose (50) or LD₅₀. On the basis of these tests, toxicity gradings can be made (see **Table A3-11**) (Desai, 1992).

Table A3-11 : Toxicity gradings of dyes			
LD₅₀ (mg/kg)	Classification	No. of dyes	% dyes
< 25	Very poisonous		
25 to 200	Poisonous	44	1
200 to 2 000	Harmful	314	7
> 2 000	Not classified	4,103	92
Total		4,461	100

Aquatic toxicity is expressed as LC₅₀ (measured in mg/l) which gives the concentration of a chemical that causes 50% of an experimental population of fish during 48 hours. **Table A3-12** gives the results of a study carried out by ETAD on 3 000 commonly used dyes (Desai, 1992).

Table A3-12 : Fish toxicity levels of common dyes	
LC₅₀ (mg/l)	% of dyes
< 1	2
1 to 10	1
10 to 100	27
100 to 500	31
> 500	28

Some dyes have been identified to be mutagenic in the Ames *Salmonella* mutagenicity test and some disperse dyes have been shown to cause allergic contact eczema.

It is difficult to assess toxicity in terms of structure as a simple change in the position of substituents etc. can alter the toxicity. ADMI carried out a survey in 1971 on the toxicity of 46 dyes tested on fish. The results of this study showed that basic dyes were the most toxic due to their cationic nature, whereas direct and vat dyes were found to be non-hazardous.

From this and other ADMI-sponsored studies, it was concluded that basic cationic dyes and some acid and disperse dyes warrant being labelled "potentially hazardous". Overall, all dye containing waste should be considered potentially hazardous as neither the effect on human health nor what occurs on decolourisation is known.

Brown and Anliker (1988) summarised the effects of textile effluent on the environment and the toxicity with respect to fish and other aquatic organisms, sewage bacteria and plants. They concluded that due to the vast number of different dyestuffs and processes in which they can be applied, an accurate environmental risk assessment can only be made on individual

dyestuffs and in individual dye-houses. A similar summary of research work initiated by the ADMI into the toxicity of dyes to aerobic and anaerobic bacteria and to fish is given by Vyas (1975).

A3.12 Heavy Metals

The source of heavy metals in dyes is from premetallized dyes (3% to 4% metal); basic dyes requiring preparation as a double salt of zinc; dichromates to oxidise and fix dyes; and chromium compounds from after chroming operations in wool dyeing.

Table A3-13 : Heavy metal content of dyes		
Metal	Typical conc. (ppm)	Dye type with highest metal content
Arsenic	< 1 to 1.4	reactives
Cadmium	< 1	all types
Chromium	3 to 83	vat
Cobalt	< 1 to 3.2	acid
Copper	33 to 110	vat
Lead	6 to 52	reactives
Mercury	0.5 to 1	vat
Zinc	3 to 32	basic

The discharge for heavy metals are stringent as they can be toxic to animals and aquatic life. Metal complex dyes contain chelated chromium, cobalt, copper and nickel. Some cationic dyes contain zinc and trace concentrations of mercury, cadmium and arsenic can be present as impurities from intermediates. **Table A3-13** lists the metal content of some dyes (EPA, 1996; Cooper, 1978).

Some oxidising and reducing agents contain metals (e.g. dichromate and permanganate), but in most cases, these chemicals are no longer in use. Metals are also present in finishes such as antifungal and odour-preventive finishes, water repellents and flame retardants (EPA, 1996).

A3.13 Biodegradability

Dyes are stable against breakdown by many micro-organisms and most dyes do not biodegrade under the aerobic biological treatments in a municipal sewage plant. Many dyes, including the azo dyes, degrade under anaerobic conditions and the aromatic amines thus formed have been found to degrade further aerobically. Therefore, the aerobic conditions of rivers and lakes should degrade the amines formed from the biodegradation of azo dyes if they accumulate in the river sediments.

Due to this recalcitrant nature of dyestuffs under aerobic processes, concern arose as to the toxicity of these compounds towards the micro-organisms. A screening method for determining the inhibitory effect of the dyestuffs on aerobic bacteria was developed by ETAD (Brown et al., 1981). Tests were performed on 202 dyestuffs and the results reported as the 50% Inhibition Concentration (IC₅₀) values. Dyes from the direct, disperse, reactive, vat, mordent, pigment,

acid and solvent ranges gave IC_{50} values greater than 100 mg/l thus indicating that they had no toxic effect towards the micro-organisms at the concentration expected in textile effluents. However, dyes belonging to the basic range gave IC_{50} values of less than 100 mg/l, which is in agreement with the results obtained by Ogawa et al. (1989) that basic dyes are inhibitory to micro-organisms. From these tests, and the general experience of ETAD, it was concluded that although dyes may cause concern at sewage works due to their colour, there should be no concern as to their toxicity. The exception to this ruling are the benzidine-based dyes, the manufacture of which is prohibited by ETAD members. This has resulted in some ETAD members resigning from the board (ETAD Annual Report, 1993).

Finishing chemicals and dyes have BOD's of between 1% and 26% of the COD, which is far below the ratio required for easily biodegradable wastes. Typically, a COD/BOD ratio of textile effluents is 2.5:1 to 5:1. If the ratio is greater than 5:1, biodegradability is a problem (Laing, 1991).

A3.14 Bioelimination

Some dyes are adsorbed 40% to 80% by the biomass. Of 87 dyes studied, 62% had significant colour removal due to sorption. This is referred to as bioelimination. With acid dyes, their high solubility causes low adsorption and this is based on the number of sulphonic acid groups. Reactive dyes also show little adsorption, but this however, is not dependent on the sulphonated groups or ease of hydrolysis. Direct and basic dyes show high adsorption and disperse dyes show high to medium **adsorption**.

A3.15 Dye Degradation Products

Moll (1991) summarised the carcinogenic potential of dye degradation products. Information on the carcinogenic effect of dyes on animals was only available for a limited number of dyes, most of which were azo (approximately 70% of all colourants on the market are azo dyes). The toxicity of these dyes was assessed in terms of azo separation, i.e. what aromatic amines are produced. This occurs through reduction of the azo bond or the influence of enzymatic systems. The main concern is for those azo colourants which can release carcinogenic amines during metabolism. In 1994 the German government banned the use of azo dyes that can be split into any of 22 listed amines (see **Table A3-14**; Turner, 1995). This ruling applies to any consumer goods that remain in contact with the body for extended periods of time. While the majority of ETAD members do not manufacture or sell azo dyes affected by this regulation, there are some exceptions. ETAD issued a statement in 1995 that all manufacturing companies must inform their customers whether they comply with these regulations. A review by Clarke and Steinle (1995) reports that although it is estimated that about 150 azo dyes currently commercially available would form, on reductive cleavage, an aromatic amine that is acknowledged to be an animal carcinogen, only about 15 of these aromatic amines are considered to be relevant to the colourant industry. In most cases, the reduction products of

the azo dyes are aromatic aminosulphonic acids, which have little or no carcinogenic potential (Jung *et al.*, cited by Clarke and Steinle, 1995).

Table A3-14 : Carcinogenic aromatic amines (after Turner, 1995)	
4-aminodiphenyl	3,3'-dimethylbenzidine
benzidine	2-methoxy-5-methylaniline
2-amino-5-chlorotoluene	3,3'-dimethyl-4-4'-diaminodiphenylmethane
2-aminonaphthalene	4,4'-methylene-bis(2-chloroaniline)
2-aminoazotoluene	4,4'-oxydianiline
2-amino-4-nitrotoluene	4,4'-thiodianiline
4-chloroaniline	2-aminotoluene
2,4-diaminoanisole	2,4-diaminotoluene
4,4'-diaminodiphenylmethane	2,4,5-trimethylaniline
3,3'-dichlorobenzidine	2-methoxyaniline
3,3'-dimethoxybenzidine	4-aminoazobenzene

A3.16 Auxiliaries

The pollution potential of other contaminants is high (Laing, 1991). The most obvious source are the additives to the dyebath, but there can also be impurities present from the manufacturing processes. From a study in the USA, it was concluded that of the total BOD load of textile effluents, dye wastes only contribute 10% to 30%. Acetic acid alone can contribute 50% to 90% of the dyehouse BOD. Another study showed that dyes contribute only 2% to 5% of the COD, whereas chemicals contributed 25% to 35% (including levelling, anti-foaming and wetting agents etc.). Two of the main sources of contaminants are the electrolytes added to the dyebath to aid in exhaustion and surfactants. Others include toxic organic chemicals (e.g. acetone, chloroform, methylene chloride and cyclohexane), biocides and toxic anions (EPA, 1996).

A3.17 Energy Considerations in the Textile Industry

The textile industry is a large user of energy and in South Africa, it is the second largest user of electricity from Eskom. The main areas of energy use are in drying, followed by heating and air-conditioning. The main sources of energy and their use in the industry are listed in **Table A3-15**.

The energy utilisation for the various stages in the processing of fabric for T-shirts and bed linen are given in **Table A3-16** (Jensen *et al.*, 1995).

Table A3-15 : Energy sources and use in the textile industry	
Energy type	Use
Synthetic natural gas	boiler fuel to generate steam direct fired furnaces
Electricity	machinery motors air-conditioning lights offices stenters
Fuel oil	boiler fuel standby for natural gas boilers truck fleets stenters
Coal	boiler fuel
Propane	standby for natural gas

Table A3-16 : Energy utilisation in the processing of fabric for T-shirts and bed linen	
Process	MJ / kg product
Production of raw materials	
Cotton production	48.60 (per kg baled lint)
Polyester fibres	111.50 (per kg fibre)
Mechanical processes	
opening, carding, combing, spinning	50.00 - 150.00
warping, knitting	16.70 - 66.70
warping, sizing, weaving	28.60 - 85.70
Total knitting	67 - 217
Total weaving	79 - 236
Wet treatment (T-shirts)	
scouring / washing	2.10 - 14.70
bleaching / washing	3.50 - 29.60
dyeing	2.80 - 8.00
drying	5.80 - 19.20
Total	14 - 71
Wet treatment (bed linen)	
desizing/scouring/ washing	2.54 - 12.41
bleaching/ washing	4.79 - 13.40
mercerising	4.94 - 9.17
dyeing	1.55 - 5.15
drying	8.80 - 22.33
resin finishing	5.06 - 10.00
Total	28 - 72

The implementation of measures to minimise the use of energy will result in substantial savings for the industry. For example, the installation of a heat exchanger on a continuous process will result in a 70% recovery of energy.

A3.18 Conclusions

The textile industry emits a wide variety of pollutants from all stages in the processing of fibres and fabrics. These include liquid effluent, solid waste, hazardous waste, emissions to air and noise pollution. The consumption of energy must also be taken into account as the fuel used to provide this energy contributes to the pollution load. It is important to investigate all aspects of reducing wastes and emissions from the textile industry, as not only will it result in improved environmental performance, but also substantial savings for the individual companies.

A3.19 References

All refereneces are listed in **Appendix 5**.

Appendix 4

End-of-pipe Treatment Methods

Once waste minimisation has been carried out in the factory, effluent will still be produced that will require some form of treatment prior to disposal to sewer, river or sea. This appendix will summarise the available technology for treating textile effluent for colour removal and list some of the treatment plants in operation at various textile mills around the world.

A4.1 Effluent Segregation

Prior to the installation of any end-of-pipe treatment method, it is essential to carry out segregation of the effluent streams to separate the contaminated streams from the relatively *clean* streams for treatment. This results in a more effective treatment system as a smaller volume of waste water is treated (resulting in lower capital and operating costs) and it allows for the use of specific treatment methods rather than trying to find one method to treat a mixture of waste with different characteristics. The segregated *clean* streams can then be reused with little, or no, treatment elsewhere in the factory.

A4.2 Treatment Technologies

There are 2 possible locations for treating the effluents, namely, at the textile factory or at the sewage works. The advantage of treatment at the factory is that it could allow for partial or full re-use of water. The following technologies have all been used :

- w coagulation and / or flocculation
- w membranes (microfiltration, nanofiltration, reverse osmosis),
- w adsorbents (granular activated carbon, silica, clays, fly ash, synthetic ion-exchange media, natural bioadsorbents, synthetic bioadsorbents),
- w oxidation (Fenton's reagent, photocatalysis, advanced oxidation processes, ozone), and
- w biological treatment (aerobic and anaerobic).

Since the effluent from the textile industry is complex and variable, it is unlikely that a single treatment technology will be suitable for total effluent treatment and water recycling. A comprehensive review of these technologies is given by Southern (1995).

A4.2.1 Coagulation and/or Flocculation

Chemicals are added that form a precipitate which, either during its formation or as it settles, collects other contaminants. This precipitate is then removed either through settling or by floating it to the surface and removing the sludge. This is a well-known method of purifying water. Both inorganic (alum, lime, magnesium and iron salts) and organic (polymers) coagulants have been used to treat dye effluent to remove colour, both individually and in combination with one another. With the changes in dyes and stricter discharge limits on colour, inorganic coagulants no longer give satisfactory results. They have the added disadvantage of producing large quantities of sludge. Organic polymers show improved colour removal and produce less sludge, but then may have detrimental effects on the operation of the sewage works. Cationic polymers have also been shown to be toxic to fresh water fish.

Alum is effective in removing colour from textile effluent containing disperse, vat and sulphur dyes, but is ineffective against reactive, azoic, acid and basic dyes. However, it does have the advantage of reducing phosphorous levels, thereby improving the operation of sewage works.

A4.2.2 Membranes

The membrane methods that are available for effluent treatment are microfiltration, ultrafiltration, nanofiltration and reverse osmosis. In general, nanofiltration or reverse osmosis are the most effective processes for removing colour and recovering water. The drawbacks of these processes are the high capital costs, the fact that the concentrated effluent still has to be treated, and membrane fouling.

The most frequently tested method is **reverse osmosis**. The effluent is forced under moderate pressure (1.5 to 4 MPa) across a semi-permeable membrane to produce a purified permeate and a concentrate. This process can remove up to 99% of salts and the complete removal of most organic compounds. The concentrate will require further treatment prior to disposal as the level of impurities are up to six times that of the original effluent stream.

In **nanofiltration**, the membrane acts as a molecular filter, retaining polyvalent ions and compounds with a molecular mass greater than 200. The concentrate contains almost all of the organic impurities and a large proportion of the polyvalent inorganic salts and requires further treatment prior to disposal. The permeate contains the monovalent ions (e.g. Sodium and chloride ions). This method of effluent treatment has been found to be effective in the treatment of dyebaths from reactive dyeing where sodium chloride is used as the electrolyte, as the permeate produced contains the salt and is virtually colourless, and therefore, suitable for reuse in the reactive dyeing process, saving both water and the cost of the salt.

Ultrafiltration and **microfiltration** as stand-alone treatment methods are only suitable for reducing COD and suspended solids from solution. They are effective in combination with other treatment methods such as coagulation/flocculation. They are also useful for the partial removal of colour and organics prior to discharge to sewer. Microfiltration removes colloidal material such as disperse and vat dyes.

A4.2.3 Adsorbents

In order for an adsorbent to work effectively, the concentration of the impurities in the effluent stream must remain fairly constant to prevent the release of the adsorbed material back into the effluent if the concentration falls.

Activated carbon is the most commonly used adsorbent and it is effective in removing organic components from the effluent (but not inorganic compounds). Once saturated, it must be regenerated or disposed of. Regeneration is costly, and in most cases it is trucked off site and disposed of in landfill. Care must be taken with the disposal method as the organics may leach out over time and cause pollution problems at a later date.

Other adsorbents include inorganic compounds such as silica, cinder ash and various clays. Trade name adsorbents such as Macro-sorb and COLFLOC have been shown to be effective at removing colour from reactive dyebath effluent, although disposal of the sludge may be problematic.

Bioadsorbents are naturally occurring polymers that are biodegradable and have structures that allow the adsorption of species within them, or which act as ion-exchangers. Synthetic cellulose bioadsorbents have also been developed and preliminary investigations into their use for removing colour due to reactive dyes show promising results (Southern, 1995).

A4.2.4 Oxidation

Oxidants decolourise dyes by breaking down the dye molecule. Commonly used processes are ozone and Fenton's Reagent.

Ozone has been investigated in a number of studies. It has been found that dye wastewaters react differently depending on the composition. Effluent containing sulphur and disperse dyes are difficult to decolourise, whereas colour due to reactive, basic, acid and direct dyes is removed fairly easily. The main drawback with installing an ozonation plant is the high capital

and operating costs. However, improvements in generator and contacting equipment design, together with increasingly strict environmental legislation will probably lead to a more widespread application.

Fenton's Reagent consists of ferrous salt (usually sulphate) and hydrogen peroxide. The reaction is carried out at a pH of 3 and involves the oxidation of ferrous ion to ferric ion with the simultaneous production of the hydroxyl radical. This radical is a powerful oxidising agent and will attack organic compounds and cleave the bonds. In the case of dye molecules, this would lead to decolourisation. A disadvantage (in terms of costs for the discharger) is the production of ferric hydroxide sludge, but it is thought that this sludge is advantageous to the biological treatment system.

Other oxidation methods include the use of ultraviolet light in conjunction with a photocatalyst (titanium dioxide), or other chemical agents such as hypochlorite (the use of which is not encouraged as chlorinated organic species may be formed which are themselves toxic to the environment).

The main drawback of these above methods is that it is not known what degradation products are formed from the oxidation process and it may be the case that these end products, although colourless, may be more toxic than the original dye molecules.

A4.2.5 Biological Treatment

Aerobic treatment

The majority of sewage works are based on the principle of aerobic treatment, where the incoming effluent is exposed to bacteria which convert the components into carbon dioxide and sludge, which is then sent to an anaerobic digester for further treatment. It has been found by a number of researchers that aerobic treatment methods are not sufficiently able to treat the colour from the textile industry, and any colour removal that does take place is due to adsorption onto the sludge, rather than degradation of the dye molecule.

Anaerobic digestion

Anaerobic digestion is the biodegradation of complex organic substances in the absence of oxygen to yield carbon dioxide, methane and water. It is an effective process for treating high COD wastes (e.g. size, desize washing and scouring) and the methane that is produced can be utilised as energy for heating etc. The reducing conditions in an anaerobic digester have been found to cause decolourisation of azo dyes through cleavage of the azo bond and subsequent destruction of the dye chromophore. Complete mineralisation of these degradation products does not take place and aromatic amines may be present in the effluent from the digester (Carliell et al., 1995).

A4.3 Summary

Table A4-1 discusses the available treatment technologies, together with the advantages and disadvantages of each method (Southern 1995). **Table A4-2**, lists various effluent treatment plants that are in operation both locally and internationally. A summary of the treatment methods suitable for each effluent stream produced by the textile industry is given in **Table A4-3**.

Table A4-1 : Summary of available textile effluent treatment technologies			
Technology	Examples	Advantages	Disadvantages
Coagulation/flocculation	alum lime iron polyelectrolytes	<ul style="list-style-type: none"> * simple equipment * relatively rapid colour removal * significant reduction in COD 	<ul style="list-style-type: none"> * large volumes of sludge may be generated * continual addition of chemicals * high running costs * carry-over of polyelectrolytes may affect sewage works * product generally unsuitable for reuse * will not remove reactive dyes * precise pH control necessary
Membranes	reverse osmosis nanofiltration ultrafiltration	<ul style="list-style-type: none"> * removes impurities of particular molecular masses * good colour removal * fast * can handle large volumes * removes ions 	<ul style="list-style-type: none"> * high capital costs * some effluent cannot be treated * concentrate contains almost all impurities * concentrate must be treated by another technology prior to disposal * impurities in purified stream may be too high for re-use * regular cleaning is required * pretreatment required * precise pH control necessary
	Dialysis or continuous deionisation	<ul style="list-style-type: none"> * purified stream could be re-used * cation stream could be re-used to regenerate water softener, or as caustic or carbonate in the dyeing process 	<ul style="list-style-type: none"> * portion of the effluent is not treated * concentrate contains almost all impurities * at least one of the concentrates must be treated by another technology * organic material could foul membranes * non-ionic species are not removed * capital and operating costs not known
Adsorbents	activated carbon, silica, charcoal, peat, synthetic polymers etc.	<ul style="list-style-type: none"> * good colour removal * simple technology * low operating costs for some adsorbents * removal of solvents 	<ul style="list-style-type: none"> * high capital costs * slow * regeneration or disposal costs * no single adsorbent is suitable for all dye types * required dosage may be high
Oxidation	Ozone Fenton's reagent UV/peroxide UV/catalyst chlorination	<ul style="list-style-type: none"> * good colour removal * can handle large volumes * rapid decolourisation * simple operation * sludge enhances sewage works operation * good colour removal * powerful oxidant * effective at destroying organic compounds * inexpensive * good colour removal 	<ul style="list-style-type: none"> * high capital costs * high operating costs * not effective at removing colour from all dye types * unknown oxidation products * unknown oxidation products * high running costs * high capital costs * unknown oxidation products * chlorinated byproducts
Reduction	tin chloride hydrosulphite	<ul style="list-style-type: none"> * good colour removal * effective for decolourising azo dyes 	<ul style="list-style-type: none"> * aromatic amines may be formed * incomplete degradation

Technology	Examples	Advantages	Disadvantages
Biological	Aerobic	<ul style="list-style-type: none"> * suitable for removing colour due to insoluble dyes * usually results in mineralisation of dyes 	<ul style="list-style-type: none"> * does not remove colour due to soluble dyes such as reactives * large volumes of sludge are generated * large energy requirements
	Anaerobic	<ul style="list-style-type: none"> * non-specific colour removal * decolourises most dyes through reduction mechanism * methane produced can be used as energy on-site 	<ul style="list-style-type: none"> * unknown degradation products * high capital cost
Evaporation		<ul style="list-style-type: none"> * concentrates effluent stream * product water suitable for reuse 	<ul style="list-style-type: none"> * does not "treat" colour * high capital costs * high operating costs
Irrigation		<ul style="list-style-type: none"> * inexpensive 	<ul style="list-style-type: none"> * detrimental effect on soil * suitable only for uncoloured and non-toxic streams * unacceptable to authorities

Table A4-2 : Some operational textile effluent treatment plants						
Location & Date	Situation	Technology	Process steps	Flow (k l /d)	Results	Ref.
Germany, 1982	dye machine	coagulation (COLFLOC)	* Inject polyelectrolyte into dyebath discharge	600	* 60 % colour removal * effective for anionic dyes	1
Germany, 1982	factory discharge	coagulation (COLFLOC)	* inject polyelectrolyte into final effluent * discharge floc to sewage works	2 000	* 70 % colour removal * effective for anionic dyes	1
Germany, 1982	sewage works	coagulation (cationic poly)	* inject polyelectrolyte into activated sludge	6 000	* 60 % colour removal	1
Germany, 1983 Lorrach Wiese Valley	sewage works	biological	* activated sludge * anaerobic digestion of sludge	100 000		2
Germany, 1990 Grenzach	factory discharge	membrane (tubular NF)	* direct membrane treatment * salt water recycled * wet air oxidation of concentrate	700		1
Japan, 1974 Kanebo	factory discharge	ozone GAC	* holding tank * 2 ozone reactors * GAC * pH adjustment	3 300	* BOD and COD reduced by 60 to 80 % * good colour removal * no sludge produced	3
Japan, 1977 Kyoto	sewage works	biological	* activated sludge process	40 000	* poor colour removal	1
RSA Mooi River Textiles	factory discharge	biological	* aerated lagoon * biofilter * maturation ponds * river	1 000	* COD reduced from 320 to 50 ppm	4
RSA, 1963 DaGama King Williams Town	factory discharge	land	* land * dairy farming	5 000	* currently being phased out (1999)	4
RSA, 1963 DaGama East London	factory discharge	biological	* flocculation * bio-filter * maturation ponds * river	4 500	* effluent complied with general standard	4
RSA, 1971 Mondi paper	sewage works (textile, domestic)	biological, coagulation, carbon	* activated sludge * alum * filtration * foam flotation * granulated activated carbon beds	10 000	* water recycled for paper making	5
RSA, 1988 Hammarisdale Waste Water Treatment Works	sewage works (textile, domestic)	biological	* alum added to activated sludge		* colour unacceptable * non compliance with regulations	6
RSA, 1989 Dyefin textiles	factory discharge	oxidation (ferrous sulphate)	* addition of ferrous sulphate * addition of caustic * sewer	300	* colour reduced	5

Location & Date	Situation	Technology	Process steps	Flow (k l/d)	Results	Ref.
RSA, 1994 Mym Textiles Umzinto	factory discharge segregated scour rinse and dye streams	membrane	* hyperfiltration * recycle of permeate	200 to 300	* permeate recycled * membrane fouling * expensive	5
RSA, 1995 Ninian & Lester	factory discharge	oxidation (Fenton's reagent)	* effluent segregation * pH reduced to 3 with sulphuric acid * ferrous sulphate addition * hydrogen peroxide addition * lime addition * discharge to sewer	800	* no colour entering sewage works * sludge enhances sewage work operation	5
RSA, 1993 Dyefin Textiles	factory discharge	oxidation (Fenton's reagent)	* effluent segregation * pH reduced to 3 with sulphuric acid * ferrous sulphate addition * hydrogen peroxide addition * lime addition * discharge to sewer	800	* no colour entering sewage works * sludge enhances sewage work operation	0
RSA, 1995 Standard Textile	factory discharge	oxidation (Fenton's reagent)	* effluent segregation * pH reduced to 3 with sulphuric acid * ferrous sulphate addition * hydrogen peroxide addition * lime addition * discharge to sewer	800	* no colour entering sewage works * sludge enhances sewage work operation	5
Sweden, 1976	factory discharge	alum	* addition of alum * flotation * sludge to press	2 880	* reduced COD from 400 to 100 mg/l	7
Switzerland, 1990	factory discharge	membrane (tubular NF)	* membrane treatment * salt / water recycle	250		1
Taiwan, 1990 Far Eastern Textiles	factory discharge	COLFLOC	* equalisation * COLFLOC * alum * flotation * sludge dewater		* good colour removal	1
Turkey, 1990 Erdogan	factory discharge	biological	* nutrient addition * activated sludge	110	* COD reduced from 1 200 to 600 ppm * produced 0.12 kg/l sludge	8
Turkey, 1990 Kom	factory discharge	ferrous sulphate, lime	* ferrous sulphate and lime addition * settling * sludge to press	700	* COD reduced from 600 to 360 ppm * produced 2.9 kg/k l sludge	8
UK, 1978 printing	factory discharge	alum	* alum, lime coagulation * flotation * recycle	2 700	* good colour removal	9
UK, 1988 carpet weaver	factory discharge	membrane (tubular UF)	* direct membrane treatment * permeate recycled * concentrate to tanker	190	* reported to be successful	10

Location & Date	Situation	Technology	Process steps	Flow (k l/d)	Results	Ref.
UK, 1990 Leek Sewage Works	sewage works	activated sludge ozone	* activated sludge * balancing lagoons * sand filters * ozone	17 424	* decrease in colour	3
UK, 1995 Courtaulds Textiles	factory discharge	adsorption (Macrosorb) coagulation	* balancing * acid * Macrosorb * alkali * coagulant * separation		* 50% of clarified effluent is reused for dyeing * effluent meets colour standards	11
USA, 1975 Alabama	factory discharge	oxidation	* electro-coagulation with aluminium * flotation	320	* effluent recycled	1
USA, 1976 Salem carpet	factory discharge	oxidation (chlorine)		7 200	* treated effluent recycled	12
USA, 1977 Vernon	sewage works	biological, carbon (PACT)	* carbon addition to aeration tank * wet air regeneration	13 000	* colour removed	13
USA, 1977		encapsulation of solids	* reaction of metal ions with silicates to form insoluble metal silicates * addition of polymer to form solid gel * waste disposal	1 600 mobile	* heavy metals removed	14
USA, 1980 (75% PE, 25% cot)	factory discharge	coagulation, biological	* lime and poly coagulation * aerated lagoon	2 700	* ADMI reduced from 100 to 75	15
USA, 1980 (80% PE, 20% cot)	factory discharge	biological	extended aeration	3 300	* ADMI reduced from 1300 to 500	15
USA, 1980 Vernon	sewage works	Powdered activated carbon	* activated sludge * powdered activated carbon with aeration tank * wet air regeneration	24 500	* ADMI reduced from 300 to 30	16
USA, 1980 (100% PE)	factory discharge	biological, coagulation	* activated sludge * alum and poly coagulation * sludge to centrifuge	2 700	* ADMI reduced from 1 340 to 110	15
USA, 1981 Penn Dye and Finish Co.	factory discharge	biological	* activated sludge * alum * settling * centrifuge	7 500	* colour reduced by 63% * BOD reduced by 76%	17
USA, 1982 Pennsylvania (bleach wash)	factory discharge	biological	* activated sludge * sludge to anaerobic lagoon	340	* COD reduced from 2 080 to 380 ppm	18
USA, 1969 Hollitex carpets	factory discharge	adsorption	granulated activated carbon	1 900	* 80% of effluent recycled	19
USA, 1989 East Burlingam	sewage works	biological, powdered activated carbon	* activated sludge * powdered activated carbon with aeration tank * wet air regeneration	45 000	* complete colour removal	20

Table A4-3 : Suitable effluent treatment methods for specific textile processing effluents								
Process	Effluent problems	Coagulation / flocculation	Adsorption	Membranes ¹	Oxidation	Aerobic	Anaerobic	Other
Sizing								
starch size	COD, BOD, SS					X	X	
synthetic size	BOD, COD, SS			X			X	
Desizing								
cotton / blends	COD, BOD, SS, TDS			X		X	X	
Scouring								
cotton / blends	BOD, TDS, colour					X	X	Evap.
synthetic	BOD, TS					X	X	
wool	pH, BOD, TS					X	X	
Bleaching								
cotton / blends	SS, peroxide			X				
synthetic	SS, peroxide			X				
wool	SS			X				
Mercerising								
cotton / blends	alkaline, TDS			X				Evap.
Dyeing								
reactive	colour, BOD, TDS, metals			X ²	X		X ³	
vat		X	X	X	X	X	X ³	
disperse		X		X	X	X	X	
direct		X	X	X	X		X	
acid				X	X	X	X	
basic			X	X	X	X	X	
sulphur		X		X	X	X	X	
Printing								
all fabrics	colour, BOD, SS	X				X	X	
Finishing								
cotton / blends	TDS, BOD	X						
synthetics	TDS, BOD	X						

Note :¹ **With possible recycle**² **If NaCl is used as the electrolyte, nanofiltration will remove the colour while allowing recycle of the salt and water for reuse in dyeing**³ **Dyes based on the azo chromophore will be decolourised anaerobically**

A4.4 Conclusions

The methods indicated for each process in **Table A6-3** are those that have been found to be the most suitable for that particular effluent stream. It highlights the importance of segregation of the various streams in order to treat them individually.

In general, effluents that are high in COD are most effectively treated by biological methods, either aerobic or anaerobic. There are a number of methods for removing colour from effluents, depending on the class of dye used, but the most effective over the range of dyes is oxidation methods (such as Fenton's Reagent) or membrane treatment using reverse osmosis. Effluents that are high in BOD and SS are best removed through coagulation and flocculation methods followed either by settling or dissolved air flotation. Those effluent streams containing alkaline (mercerising and bleaching) can be treated by membranes (ultrafiltration) or evaporation and reused in the same process. The same is true for synthetic sizes where they can be recycled after filtration.

As mentioned previously, there is no one single treatment technology that can effectively treat the final effluent from the textile industry and a combination of the available methods is necessary in order to achieve the required discharge standards.

A4.5 References

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Appendix 6

Supporting Data

This Appendix contains the data to support calculations and estimates that were made in the Worksheets. Benchmarking data on batch and continuous processing is also included.

DETERMINATION OF TYPICAL AND TARGET WATER USE FIGURES

(Worksheet A2)

The typical water use figures were determined from literature and previous surveys conducted by the Pollution Research Group in the textile industry.

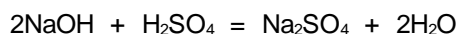
For the various batch operations (e.g. jig, jet, beam and yarn processing), typical liquor ratios were used (from literature) and it was assumed that the number of baths in a dyeing operation could vary from 8 (single dye type) to 16 (e.g. reactive/disperse dyeing). For preparation processes (bleaching, scouring etc.) it was estimated that between 3 and 4 baths would be used.

Target figures were calculated based on the typical water use figures, experience with waste minimisation in the textile industry and literature (i.e. information on new equipment and processes etc.). For example, in batch dyeing operations, the number of baths used can be reduced by reusing preparation baths with reconstitution, cascading rinses and reusing softening baths with reconstitution. For continuous operations such as desizing, scouring, and bleaching, water use can be reduced by using counter-current rinsing and by combining the operations. For printing, the water use can be decreased by counter current water flow in the washing-off stages, and turning the water off when the machine is not in use. Blanket washing water can be recycled for reuse. Screen washing can be made more efficient by removing excess paste prior to washing and using modern equipment

CALCULATION OF CAUSTIC SODA AND SULPHURIC ACID SAVINGS

(Worksheet A5)

The following chemical reaction takes place between caustic soda and sulphuric acid :



Stoichiometrically, this means that 1 mol of sulphuric acid (100%) will neutralise 2 mol caustic soda (100%). Using molecular masses, 98 g acid (100%) will neutralise 80 g caustic. Therefore, to neutralise a given mass of caustic (calculated in (c)), the mass of sulphuric acid (100%) is given by:

$$(\text{mass caustic} \times 98) / 80 = \text{mass caustic} \times 1.225$$

Therefore, the mass of 98% sulphuric acid required to neutralise the caustic is given by ;

$$(\text{mass caustic} \times 1.225) / 0.98 = \text{mass caustic} \times 1.25$$

BENCHMARKING DATA

The following extracts were taken from a research paper by Schramm and Jantschgi entitled : *Comparative assessment of textile dyeing technologies from a preventative environmental protection point of view* (Journal of Society of Dyers and Colorists, **115**, 1999).

The paper involves comparing textile dyeing technologies in terms of water, chemical and energy consumption and dyeing efficiency. The latest generation of dyeing technology was compared to that previously used and both batch and continuous dyeing methods of woven and knitted fabrics were investigated. Process steps were defined as textile dyeing with no pre-treatment or drying. A range of fabric types were compared and these are listed in **Table A6-1**.

Table A6-2 compares the latest technologies with previously used technologies for Batch Processing. **Table A6-3** does the same for padding technologies. The comparison is carried out in terms of utility consumption (water, steam and electricity), chemical use (salt, caustic acetic acid), fibre losses and dyeing efficiency. Previous technology refers to that available during 1990 to 1995; latest technologies is taken to be that available from 1997.

Table A6-1 : List of fabric types compared for both batch and padding dyeing processes
(Schramm and Jantschgi, 1999)

Code	Fibre Type	Product Description	Type of Dyestuff	Woven / Knitted
Batch Processing				
E1	Cotton	Towelling	Reactive	Woven
E2	Cotton	Towelling	Vat	Woven
E3	Polyester / cotton	Dress fabric	Disperse and reactive	Woven
E4	Wool	Outer wear	Acid	Woven
E5	Polyester / wool	Outer wear	Disperse and acid	Woven
E6	Viscose	Lining fabric	Direct	Woven
E7	Cotton	Underwear	Reactive	Knitted
E8	Polyester / cotton	Leisure clothing	Disperse and reactive	Knitted
E9	Viscose	Ladies dress material	Reactive	Knitted
E10	Polyamide	Panty	Acid	Knitted
Continuous Processing				
P1	Cotton	Shirts	Reactive	Woven
P2	Cotton	Vocational clothing	Reactive	Woven
P3	Cotton	Towelling	Reactive	Woven
P4	Cotton	Corduroy trousers	Reactive	Woven
P5	Cotton	Corduroy trousers	Sulphur	Woven
P6	Polyester / cotton	Dress fabric	Disperse and reactive	Woven
P7	Polyester / cotton	Vocational clothing	Disperse and reactive	Woven
P8	Polyamide / cotton	Plush	Acid and reactive	Woven

Table A6-2 : Comparison of previously used methods to latest technology for batch dyeing (Schramm and Jantschgi, 1999)

No	Technol.	Fibre loss (%)	Dyeing efficiency (%)	Salt (g/kg)	Caustic ¹ (m l/kg)	Hydros (g/kg)	Acetic acid ² (ml/kg)	Water (l/kg)	Steam ³ (MJ/kg)	Electricity ³ (MJ/kg)
E1	Latest	<10	>80	200	14.00			25.00	4.53	0.63
E1	Previous	<10	>80	640	24.00			75.00	11.21	0.45
E2	Latest	<10	>90		135.00	30.00		22.30	4.21	0.63
E2	Previous	<10	>90		216.00	48.00		60.00	8.72	0.90
E3	Latest	<5	>95 ⁴	200	12.50			20.00	5.08	0.90
E3	Previous	<5	>90 ⁴	480	22.40			85.00	11.21	1.35
E4	Latest	<5	>95				5.60	18.90	2.84	0.45
E4	Previous	<5	>95				6.40	40.00	8.72	0.90
E5	Latest	<5	>95 ⁵				3.60	18.00	3.46	0.63
E5	Previous	<5	>95 ⁵				4.80	60.00	8.72	1.35
E6	Latest	<2	>95	54				15.70	2.64	0.54
E6	Previous	<2	>95	80				45.00	8.96	1.17
E7	Latest	<6	>80	200	14.50			25.00	4.53	0.63
E7	Previous	<6	>75	560	23.20			75.00	11.21	0.45
E8	Latest	<5	>95 ⁴	200	12.50			20.00	5.08	0.90
E8	Previous	<5	>95 ⁴	560	20.00			85.00	11.21	1.35
E9	Latest	<2	>80	150	12.50			25.00	4.53	0.63
E9	Previous	<2	>80	480	20.00		3.00	75.00	11.21	0.45
E10	Latest	<0.5	>95				4.80	11.00	3.31	0.72
E10	Previous	<0.5	>95					40.00	8.72	0.90

Notes :

Specific consumptions are given per kg dry clothing textile

¹ Caustic soda - 32.5% solution² Acetic acid - 60% solution³ Values of primary energy demand given⁴ Value quoted for disperse dyes, reactive dyes = 80%⁵ Value quoted for disperse dyes, acid dyes = 95%

As can be seen from **Table A6-2**, the latest dyeing technologies for batch processing achieve better values than the previous technologies in all cases. Modern technology results in the use of less chemicals, water and energy, with little or no effect on the dyeing efficiencies and fibre losses. Overall, chemical use was reduced by 20% to 70%, water consumption by 70%, steam use by 60% and overall energy consumption by 60%.

Table A6-3 : Comparison of previously used methods to latest technology for padding processes (Schramm and Jantschgi, 1999)

No	Technol.	Fibre loss (%)	Dyeing efficiency (%)	Salt (g//kg)	Caustic (solid) (g/ kg)	Bicarb (g/ kg)	Sod. sulph. (solid) (m l/kg)	Soda (solid) (g/kg)	Water (l/kg)	Gas ¹ (MJ/kg)	Steam ¹ (MJ/kg)	Electricity (MJ/kg) ¹
P1	Latest	<2	90-95			7			10.7	1.12	2.42	0.77
P1	Previous	<2	85-90	175	3				15.4	3.42	4.88	0.56
P2	Latest	<2	90		4				12.7	1.34	2.38	0.50
P2	Previous	<2	85	175	6				15.4	2.68	5.01	0.51
P3	Latest	<2	90		5				12.9	1.34	2.89	0.53
P3	Previous	<2	70	100	3				15.1	2.76		0.16
P4	Latest	<2	90		4				16.8	1.81	2.78	0.53
P4	Previous	<2	75	200	16		50	20	19.6	3.37	4.76	0.46
P5	Latest	<2	90		4		50		17.6	2.22		0.13
P5	Previous	2-5	80						18.8	3.37		0.13
P6	Latest	2-5	90 ²			5.5			12.6	0.90	3.15	0.83
P6	Previous	<2	90 ³	137	1			11	15.1	2.76	5.31	0.53
P7	Latest	<2	90 ³			5.5			12.6	0.90	3.18	0.60
P7	Previous	<2	90 ⁴	137	1			11	15.1	2.76	4.98	0.64

Notes :**Specific consumptions are given per kg dry clothing textile**¹ Values of primary energy demand given⁴ Value quoted for disperse dyes, reactive dyes = 85%⁵ Value quoted for disperse dyes, reactive dyes = 80%⁴ Value quoted for disperse dyes, reactive dyes = 75%

Previously used technologies for padding processing typically involved pad-dry or pad-steam processes with a trough volume of 50l, whereas the latest technologies employ a modified pad-dry sequence with a trough volume of 20l to 35l. As can be seen from **Table A6-3**, in most cases, the latest technology achieved better results than that used previously, with the overall dyeing efficiency increasing by 5%. Water consumption was decreased by 20%, steam use by 60%, gas use by 45% and total energy consumption by 45%.

Appendix 7

Useful Organisations

South African

Pollution Research Group

**School of Chemical Engineering
University of Natal
Durban
4041**

**Tel : (031) 260 3375
Fax : (031) 260 1118**

Water Research Commission

**P.O. Box 824
Pretoria
0001**

**Tel : (012) 330 0340
Fax : (012) 331 2565**

Department of Water Affairs and Forestry

**Private Bag X313
Pretoria
0001**

**Tel : (012) 299 2823
Fax : (012) 326 1780**

Umgeni Water

**P.O. Box 9
Pietermaritzburg
3200**

**Tel : (033) 341 1303
Fax : (033) 341 1349**

Textile Industry Training Board

**P.O Box 23551
Isipingo
4110**

**Tel : (031) 902 8229 / 8288 / 8293
Fax : (031) 902 8297**

Textile Federation

**P.O. Box 16278
Doornfontein
2028**

**Tel : (011) 404 2423
Fax : (011) 404 2101**

South African Dyers and Finishers Association (SADFA)	
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Western Cape ;	P.O. Box 306; Paarl; 7620 Tel : (021) 868 2230
CSIR Textile Technology	P.O. Box 1124 Port Elizabeth 6000 Tel : (041) 532131 Fax : (041) 532325
South African Bureau of Standards (SABS)	Private bag X191 Pretoria 0001
Department of Environment Affairs and Tourism (DEAT)	Private Bag X447 Pretoria 0001 Tel : (012) 310 3646 Fax : (012) 332 6287
Durban Water and Waste	P.O. Box 1038 Durban 4000 Tel : (031) 302 4783 Fax : (031) 302 4747
South African Clothing and Textile Workers Union (SACTWU)	P.O. Box 18361 Dalbridge 4014 Tel : (031) 301 1351 Fax : (031) 306 0788

International

**United Nations Environment Programme
(UNEP)
Cleaner Production**

**UNEP Regional Office for Africa
P.O. Box 47074
Nairobi
Kenya**

**Tel : (254 2) 52 1840 / 52 1841
Fax : (254 2) 62 3928**

**United States Environmental Protection
Agency (EPA)**

**MC 7409
Washington
DC 20460**

**Ecological and Toxicological Association of
Dyes and Organic Pigment Manufacturers
(ETAD)**

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**Tel : (061) 690 9966
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Society of Dyers and Colourists

**P.O. Box 244
Bradford
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BD1 2JB
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**Tel : (01274) 725138
Fax : (01274) 392 888**

Internet Sites

**South African Department of Water Affairs
and Forestry**

**[http://www-dwaf.pwv.gov.za/idwaf/
index.html](http://www-dwaf.pwv.gov.za/idwaf/index.html)**

Business and the Environment

**[Http://www.ru.ac.za/departments/
Law/SAenviro/business/business.
html](Http://www.ru.ac.za/departments/Law/SAenviro/business/business.html)**

UNEP Industry and Environment Home Page

<http://www.unepie.org/home.html>

USA Environmental Protection Agency

<http://www.epa.gov>

World Bank

<http://www.worldbank.org/>

UCLA Centre for Clean Technology

<http://cct.seas.ucla.edu/cct.pp.html>

**UK Environmental Technology Best Practice
Programme**

<http://www.etu.com/ETBPP/>

OECD	http://www.oecd.org
UNIDO	http://www.unido.org
Central Services Statistics	http:// www.css.gov.za
Rhodes University Environmental Home Page	http://www.ru.ac.za/

Appendix 8

Sample presentation

This Appendix contains a set of sheets that can be used as a presentation to introduce the concept of waste minimisation in the textile industry and explain the methodology of using this Guide. They can simply be photostatted and used as is, or modified to meet specific requirements.

Waste Minimisation Guide for the Textile Industry

A Step Towards
Cleaner Production

What is waste minimisation ?

The application of a systematic approach to
reducing the generation of waste
at source

Trainer Note:

In other words, waste minimisation prevents the waste from occurring in the first place, rather than treating it once it has been produced by end-of-pipe treatment methods.

Waste minimisation applies to:

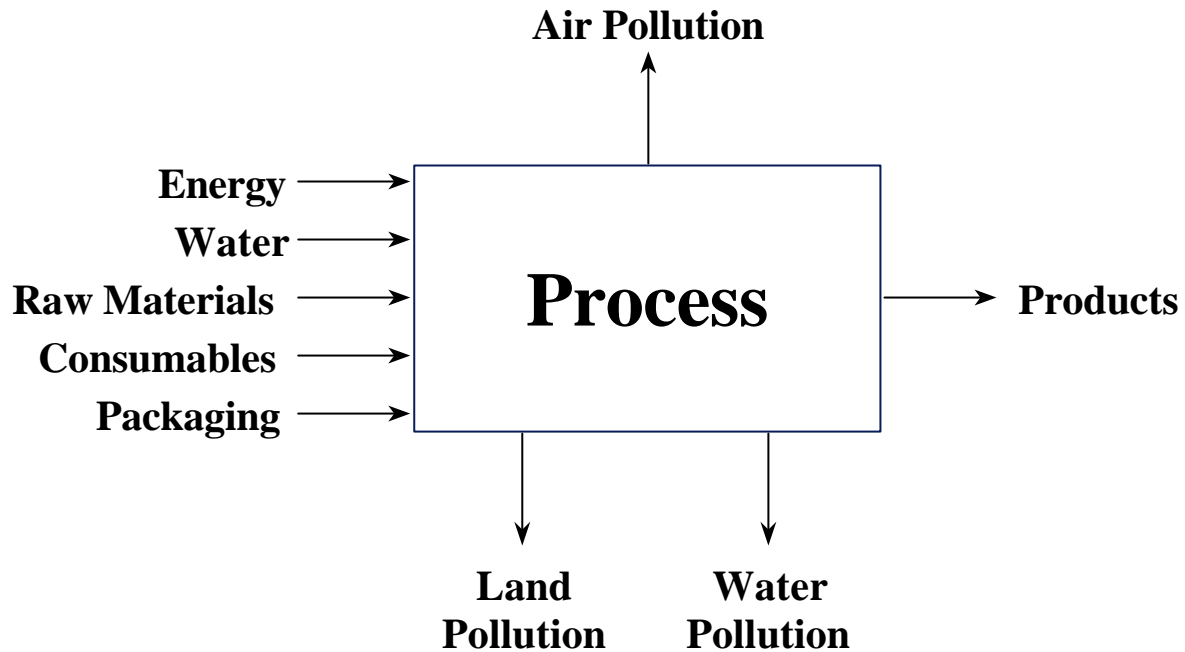
- hazardous materials
- non-hazardous materials
- water
- energy
- raw materials
- all waste emissions
- other resources

**It is NOT a once-off activity,
but an ON-GOING programme**

Trainer Note:

That is, it is a technique that can be applied to all inputs to, and outputs from, a process.

The Process Model

**Trainer Note:**

This diagram shows pictorially what was said on the previous slide. It indicates the inputs and outputs of a process. Anything that does go into the product is considered as waste.

Waste minimisation is important because it:

- reduces operating costs
- reduces risk of liability
- reduces end-of-pipe treatment
- improves process efficiency
- enhances public image
- protects health and environment
- improves employee moral

Waste minimisation makes good business sense

Trainer Note:

Remember, waste is not only materials that are excess to requirements, but represent a loss of company profits.

Scope to Save

Raw Materials	1 to 5 %
Packaging	10 to 90 %
Consumables	10 to 30 %
Ancillary materials	5 to 20 %
Electricity	5 to 20 %
Water	20 to 80 %
Effluent	20 to 80 %
Solid Waste	10 to 50 %

Trainer Note:

These are typical percentage savings that can be achieved by implementing waste minimisation on-site.

How is it done ?

- Waste minimisation is achieved through
source reduction by making
process and **product** changes

Product changes include:

- increasing product life
- designing for less environmental impact

Process changes include:

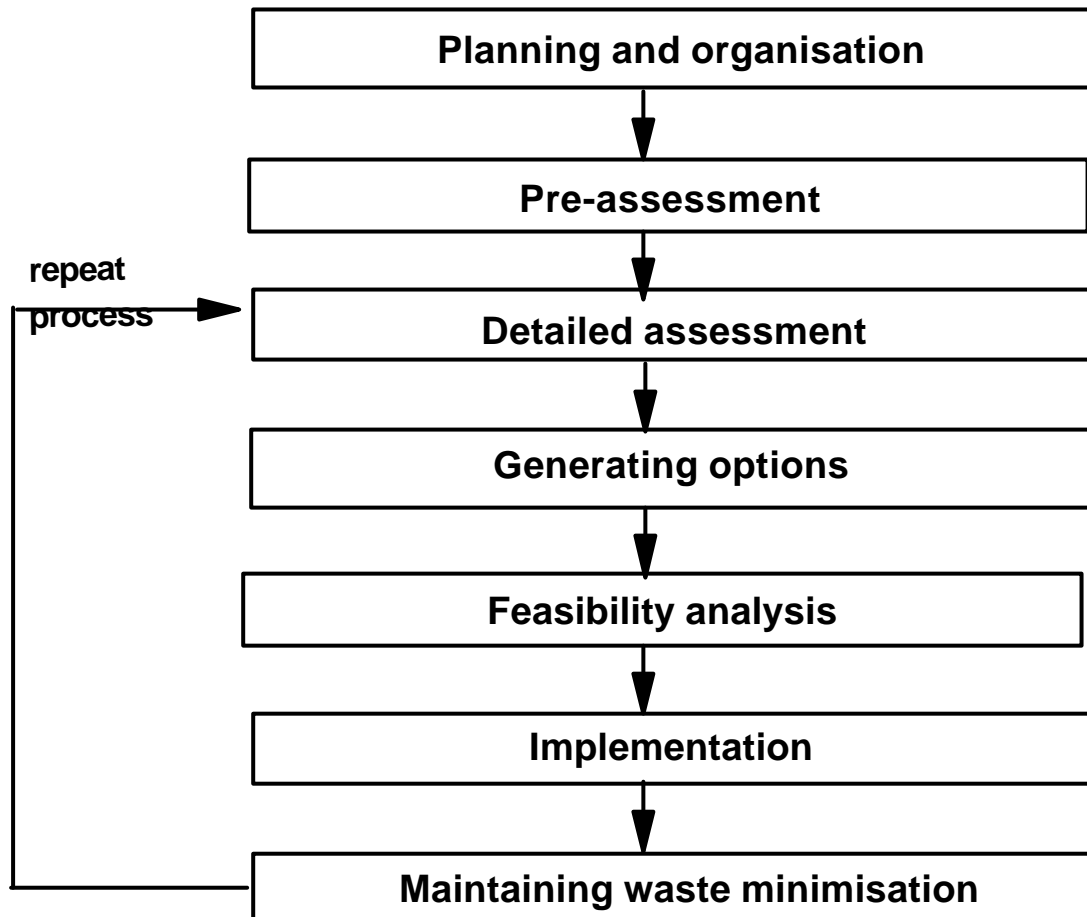
- improved operating practices
- improved housekeeping
- change in raw materials
- change in technology
- in-house reuse or recycling

End-of-pipe treatment is only considered
AFTER
source reduction

Where to start?

- Main stages:
 - ▶ planning and organisation
 - ▶ pre-assessment
 - ▶ detailed assessment
 - ▶ generate options
 - ▶ feasibility analysis
 - ▶ implementation
 - ▶ maintaining the programme

How it fits together:

**Trainer Note:**

Waste Minimisation is a methodical approach to reducing waste at source. This is the accepted approach to implementing a waste minimisation programme. Each stage will be discussed separately

Planning and organisation:

- obtain management commitment
- set up a project team
- set overall goals
- identify and overcome barriers
- conduct a pre-assessment

Trainer Note:

Obtaining management commitment is the most important step in implementing a waste minimisation programme. Without support from the top, the programme will not succeed as people have to be given the time and resources to undertake waste minimisation activities.

Who should be on the project team?

- Representatives from:
 - ▶ management
 - ▶ environmental department
 - ▶ quality assurance and control
 - ▶ design and process engineering
 - ▶ production and maintenance
 - ▶ legal department
 - ▶ finance department
 - ▶ health and safety
 - ▶ operators and
 - ▶ external consultants

Trainer Note:

The size of the project team will differ depending on the size of the company. In small companies there may be only 2 team members, while in larger companies, the team may consist of all the above people. A good team is important in order that all relevant information is collected.

Barriers to waste minimisation

- Economic
 - ▶ insufficient funds or cash flow
- Technical
 - ▶ concerns about changes in product quality
- Regulatory
- Cultural
 - ▶ fear of change
 - ▶ poor communication

Trainer Note:

These are some of the common barriers encountered when beginning a waste minimisation programme. With good internal communication and good understanding of the benefits of waste minimisation, these barriers can be overcome.

Pre-assessment

- obtain overall company information
- draw process flow diagrams
- identify all sources of wastes
- assign costs to all wastes
- evaluate wastes and emissions
- identify areas for detailed assessment

Trainer Note:

The pre-assessment involves obtaining overall information for the site. Once all waste streams have been identified, quantified and a cost assigned to them, those areas that require further investigation can be identified. This may be based on the quantity of waste produced, the hazardous nature of the waste, or the value of the waste.

Detailed assessment

- construct detailed mass and energy balances
- include:
 - ▶ water
 - ▶ raw materials
 - ▶ energy
 - ▶ effluent
 - ▶ air emissions
 - ▶ solid waste
 - ▶ products

Trainer Note:

Once the area for detailed investigation has been chosen, a detailed mass and energy balance can be prepared over this section. This will identify where the losses are occurring and highlight areas for improvement.

Generating options

- identify all areas for improvement
- identify all waste minimisation options
 - ▶ brainstorming
 - ▶ previous case studies
 - ▶ literature
- evaluate options
- identify suitable options for implementation

Trainer Note:

Options for improvement can then be identified. This is best done through brainstorming with all team members.

Feasibility analysis

- Analyse options in terms of:
 - ▶ Technology
 - will it do the job ?
 - what changes have to be made ?
 - ▶ Economics
 - capital and operating costs
 - payback period
 - ▶ Environment
 - will it reduce environmental impact ?
 - compliance with regulations ?

Trainer Note:

All options are then evaluated in terms of their technical, economic and environmental feasibility. In some cases, options have to be implemented due to legislative pressure even if they are not found to be economically feasible.

Implementation

- arrange finance
- design
- purchase equipment
- install
- commission

Simple options that require little or no capital investment should be implemented as soon as they are identified

Trainer Note:

The final stage is implementing those options found to be suitable for the company. It must be remembered that simple options that are identified during the course of the assessment phase that are obviously beneficial should be implemented at that time and not only at the end of the feasibility phase.

Maintaining the programme

- set and reassess targets
- evaluate and monitor performance
- once high priority options have been implemented, return to lower priority
- conduct periodic reviews of the programme

Waste minimisation must become entrenched in company policy

Trainer Note:

Maintaining the programme is the most important aspect of waste minimisation. It is not a once-off activity. Those projects that were identified and implemented must be revisited at regular intervals and evaluated to determine if they are still operating the way it was intended. If possible, new targets should be set and the company should strive for best practice. Options that were identified in the assessment phase and were lower on the list of priorities should also be investigated once the top options have been implemented.

What is the purpose of the guide?

To enable the textile industry to become more efficient through minimising wastes and emissions, thereby decreasing costs.

It guides the industry in:

- identifying areas of waste
- constructing mass and energy balances
- identifying suitable waste minimisation options
- determining the feasibility of implementation

Outline of the Guide

- Consists of 2 volumes
 - ▶ Volume I : 9 chapters and 8 appendices
 - ▶ Volume II : Self-assessment worksheets
- It guides a company through a waste minimisation survey by means of worksheets specifically designed for the textile industry.

Worksheets

- Divided into 5 main sections :
 - ▶ Identifying the scope for savings (A)
 - ▶ Planning and organisation (B)
 - ▶ Pre-assessment (C)
 - ▶ Detailed assessment
 - batch processes (D)
 - continuous processes (E)
 - printing (F)
 - kitchens (G)
 - energy (H)
 - ▶ Feasibility analysis (I)

Trainers Note:

Some completed worksheets are provided in Volume II to serve as an example as to the methodology of using the guide.

Worksheets A

- aimed at management
- quick reference to savings that can be achieved
- highlight areas for improvement
- determines key performance indicators
- enables benchmarking

Trainers Note:

This first set of worksheets are designed to be used as an indication of the savings in water, energy and caustic that are possible based on best practice figures. Its aim is to show management the benefits of waste minimisation, and, in this way, get them on board for the programme.

Worksheets B

- Planning and Organisation
 - ▶ determines commitment to programme
 - ▶ establishes project team
 - ▶ prepares policy statement
 - ▶ identifies goals of survey
 - ▶ conducts a SWOT analysis
 - ▶ identifies interested and affected parties

Worksheets C

- Pre-assessment:
 - ▶ obtains information on:
 - process routes
 - chemicals and dyes
 - sources of wastes
 - cost of wastes
 - ▶ identifies areas for further investigation

Worksheets D

- Detailed assessment: **batch processes**
 - ▶ used for jigs, jets, yarn etc.
 - ▶ obtain information on:
 - recipes
 - production
- guides company in calculating waste produced
- provides suggestions for minimising waste

Worksheets E

- Detailed assessment: **continuous processes**
 - ▶ washing, mercerising etc.
 - ▶ obtains information on :
 - production, recipes, flows etc.
 - ▶ calculates water use, effluent production and energy discharged to drain
 - ▶ assigns costs to waste streams
 - ▶ identifies suitable waste minimisation options

Worksheets F

- Detailed assessment: **printing**
 - ▶ determines:
 - paste wasted from drums, screens and pipes
 - waster used in blanket, screen and drum washing
 - mass of chemicals and dyes on fabric
 - ▶ identifies waste minimisation options

Worksheets G

- Detailed assessment: **kitchens**
 - ▶ guide to calculating waste from size, dye and print kitchens
 - ▶ determines:
 - water used to wash floors and mixing tanks
 - water used to prepare recipes
 - solid waste
 - chemicals and dye to drain
 - waste minimisation options

Worksheets H

- Detailed assessment: **Energy**
 - ▶ determines:
 - cost of compressed air
 - wastes due to leaks
 - cost of refrigeration
 - costs of steam generation, distribution and use
 - possible savings through waste minimisation

Worksheets I

- Feasibility analysis
- determines if an option is technically and economically feasible
- calculates capital and operating costs
- calculates savings
- determines payback

How the Guide can help the Textile Industry

- reduced operating and effluent treatment costs
- reduced environmental impact
- compliance with legislation
- aid in complying with ISO 14000

**The company will become more efficient
and globally competitive**